INSECTS AND HUMAN WELFARE

AN ACCOUNT OF THE MORE IMPORTANT RELATIONS OF INSECTS TO THE HEALTH OF MAN, TO AGRICULTURE, AND TO FORESTRY

BY

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TO

MY WIFE

PREFACE

The present volume is an attempt to present some of the principles and practices of economic entomology in a form that will illustrate the biological relationships of insects to their environment. Like nearly all applied sciences, economic entomology was early developed as an art, with little reference to biology, aiming toward the empirical application of certain methods for the destruction or abatement of noxious insects.

The past few decades have witnessed great changes whereby the field of the entomologist has been greatly extended, and he has been compelled, not unwillingly, to improve his methods of investigation and to take advantage of the rapid progress made not only in zoölogy and botany, but in medicine and chemistry as well. He has naturally greatly improved his efficiency, and has been enabled to increase his usefulness to humanity many fold.

The general public rarely appreciates fully the many economic problems in relation to insects which continually present themselves. Even the zoölogist, be he morphologist, embryologist, geneticist or student of animal behavior, often regards the entomologist as a collector or cabinet naturalist, who spends the greater part of his time impaling specimens upon slender pins, and continually rearranging them in cork-lined boxes. Unfortunately, this means toward an end seems to be a bugbear from which the entomologist may never escape, since he has to deal with a wonderfully varied and extensive series of animals. This very fact makes it difficult to deal with insects in the brief and generalized manner applicable to other groups of animals. As a consequence, entomological books and treatises naturally tend to assume encyclopaedic form.

In the following pages I have considered few of the details which may be found in many other carefully prepared volumes, but have rather attempted to avoid, as consistently as possible, matters not directly necessary for a brief consideration of insects as they affect human welfare.

Most of the material contained in the chapter on Insects and Public Health appeared in the *Scientific Monthly*, and in its recast and revised form is reprinted with their kind permission. The illustrations have come from several sources, the photographs almost entirely from negatives made by the author; of the maps, charts, etc., some have been made especially for the present book and others are redrawn or modified from various authors.

Owing to changes in nomenclature during the past few years, many of our common insects now have different Latin names. All of these changes have not been made in the present book, as the author feels that they should become well established before they are presented to the non-expert reader.

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INTRODUCTION

In his ceaseless strides towards a domination of the material world, man has encountered many obstacles. Some of these are palpably of his own making. For many of those presented by his living environment, man is responsible only in so far as he forms a part of the intimately interdependent myriad of organisms which make up that environment.

In his battle with the elements, he has continually improved his condition and he has seemingly mastered many problems which did not even disturb the minds of previous generations. It is in relation to other animals and to plants, more like himself in their plastic constitution and powers of reproduction, that he has so far experienced the greatest difficulty in turning the balance to suit his fancy.

The great variety and usefulness of domesticated animals and cultivated plants that have been selected and developed, shows that there is much in man's living environment that may be diverted to useful ends. These have been sought for and remain, at least in their present state of improvement, only as unwilling guests, ready to depart, or to revert to their former savage state at the first opportunity.

Another, and far more extensive series, of unbidden guests, is made up of numerous other animals and plants, some originally associated with the human species, and others attracted to it as the result of changes wrought by civilization. The organisms of this class consist of various disease-causing microbes and parasites, and of living things that either find a more congenial environment where the face of nature has been altered, or have actually been transferred to parts of the world where they did not formerly exist in the orderly arrangement of nature.

This great train of undesirable animals and plants is continually augmented by new arrivals, mainly through exten-

sions in the distribution of those already affected by a changed environment. A quite considerable part of this motley assemblage consists of insects, which enter into our life and activities in many ways. This group of animals really vies with the mammals, and with man in particular, in its attempt to dominate the animal world. With this end in view, insects have several points in their favor which must not be forgotten at the outset, although they are dealt with at greater length in the succeeding chapters. There are many more different kinds of insects than there are of other animals and it follows from this, if for no other reason than as a matter of chance, that they will cross our path at many places. They are small, extremely tenacious of life and endowed with such great powers for reproduction and multiplication that the abundance of any particular species responds very rapidly to changes in food supply, or other variable factors in their surroundings. Although in great part terrestrial or aquatic during their preparatory stages, they are typically winged and adapted to an aërial life in their mature condition. In addition, some are parasites of various plants, animals, and even in other insects, till it would seem that about every method of earning a living, or of securing it otherwise, may find its counterpart in some insect. Endowed as a natural consequence also with a great fixity of purpose dependent upon their purely instinctive behavior, insects do not respond readily as a class to our efforts to thrust them aside and out of our way.

What can be more persistent than the well-directed flight of the hungry mosquito in its search for human blood. Much has been learned concerning the hidden dangers that lie in the wake of the mosquito bite, but little has been accomplished toward banishing the mosquito tribe. Quite properly no biologist has entertained the idea that the instincts of the mosquito or for that matter of any other insect could be altered in the least. The only remedies which can be proposed at the present time for dangerous, annoying, or destructive insects depend upon actually destroying them,

preventing their reproduction or in actually imprisoning the objects that might be damaged, as we do for ourselves with barricades of fly screens and mosquito nets. Crude as such methods may appear to be in general principle, their application is by no means as simple as might appear at first sight, and in practice they are becoming much more efficient from year to year.

Unfortunately the vast group of insects has furnished almost no species that are directly useful to man. Only two stand out in sharp contrast; the honeybee and the silkworm. Like some of our higher domesticated animals and cultivated plants, they have been associated with man for many centuries. Indeed the silkworm has its origin hidden in antiquity and like our familiar plant, Indian corn, has never been found in the wild state. Through selection, several improved races of the honeybee have been evolved and apiculture as now followed in many countries has added greatly to the material wealth of the world through its extensive production of honey and beeswax.

The silkworm is likewise an extremely valuable insect, although its cultivation is limited to a smaller part of the world. All the real silk of commerce is produced by insects, although certain kinds are spun by other caterpillars than those of the true silkworm (*Bombyx mori*). Like the honeybee, the silkworm is known in several races with special characteristics of cocoon-color and rate of development, brought about by selection and inbreeding. For many centuries the silkworm has produced not only a vast amount of valuable material for clothing and other purposes, but has added immeasurably to the glitter of personal adornment. Quite possibly in the future the product of the silkworm may be supplanted by chemically treated wood-fibre and other inferior materials of similar appearance.

Shellac is also the production of an insect, of considerable commercial importance, and something for which no acceptable substitute has so far been evolved. It does not seem improbable, however, that the lac-insect may become obso-

lete, a fate which overtook the cochineal insect. The latter was formerly far more important as a source for carmine and the red dyes made therefrom, but has been replaced by inferior, though more cheaply produced chemical colors.

Few other insects are directly useful to an extent that makes them of general economic importance, and so much has been written of the species just mentioned that they are omitted from the following account. It is confined to those insects which bear a less pleasant relation to man and to those which are secondarily beneficial in so far as they may regulate the abundance of the primarily destructive species.

For convenience we may group insects in their relation to human welfare, into several categories as has been done in the following chapters. In their association with various diseases of man and of the higher animals, insects are of very direct importance and this aspect stands more or less clearly apart from the others. As enemies of various cultivated plants, the depredations of insects are of importance in so far as they interfere with agricultural production, decreasing the supply of foods and of other less necessary although valuable materials. Their influence upon the forests is similar to the last in many ways, but as will appear on closer examination presents different problems from the practical standpoint.

Many insects, some of them of far less real importance than some of their less sociable fellows, will be considered under the caption of household insects. These creatures, of many diverse sorts, have taken up their abode with man and are continually intruding themselves upon his attention. Some are dealt with elsewhere as they are related to diseases or have otherwise striking economic relations; the remainder, no worse than nuisances, show many interesting and surprising adaptations.

INSECTS AND HUMAN WELFARE

CHAPTER I

INSECTS AND THE PUBLIC HEALTH

SCARCELY more than two decades have elapsed since the scientific world entertained its first suspicion that certain human diseases might be spread through the agency of insects. Eighteen years have gone by since that suspicion became an established fact, and in this short space of time so much has been learned concerning the pernicious activities of these small animals in disseminating disease-causing organisms among man and the higher animals, that the science of preventive medicine can now be applied to many important diseases which were before utterly beyond its reach. Every year brings forth fresh evidence that insects are important factors in relation to public health, and adds to the list of diseases that are partially or entirely dependent upon certain insects for their spread.

A brief statement of the nature of communicable diseases and of the general habits of the kinds of insects that are implicated in carrying disease will serve to define roughly the field of medical investigation which is open to the entomologist. Communicable diseases are invariably due to parasitic organisms in the body which are capable of inducing similar symptoms in other persons or animals if transferred to healthy individuals from diseased ones. Many conditions modify the transfer of communicable diseases; some individuals are more easily infected than others; some may be immune as the result of a previous attack; and, on the other hand, the virulence of pathogenic organisms often varies greatly in accordance with conditions to which they have been subjected previously. A simple method of spread occurs with many diseases, for example typhoid fever and pulmonary tuberculosis. With the former, the *Bacillus typhosus*

which is the disease-producing organism, is present in the dejecta of an infected person and may find its way from these to food, carried by flies or otherwise; ingested by a healthy person, it may quite likely multiply and induce a second case of typhoid. With tuberculosis, the tubercle bacillus from desiccated sputum may enter the lungs of a healthy person with dust and there reproduce the disease. As we shall see later, certain insects are commonly associated with the spread of diseases of this type, although from the very nature of such diseases, insects are not exclusive factors, and may be referred to as contaminative carriers.

A second type of communicable diseases differs from the one just mentioned in that the organism which causes the disease must live for a time in the body of some other animal to undergo certain definite changes before it can again induce the disease in another individual. The most important insect-borne diseases belong to this type, for in the case of man and domestic animals, certain insects and ticks act as the secondary host animals for the organisms of many diseases. Thus, yellow fever is spread only through the agency of a certain mosquito, for in its body alone can the yellow fever organism live and undergo the changes that are necessary before it can be introduced into another patient by the bite of an infected mosquito. Malaria belongs to the same category, for it spreads only through the bite of certain mosquitoes that obtain the organisms with their meal of blood, and then afterwards inject into the blood of another person, a later stage of the malarial parasite which has developed meanwhile within the mosquito.

The importance of insects as detrimental to public health is well known to professional zoölogists, medical men, and laymen alike, but is usually emphasized only under the stress of particular circumstances, such as the safety of soldiers in the recent war, or of unusual outbreaks of diseases for which insects are directly responsible.

Insect-borne diseases present a constant menace to the world, and aside from the actual toll of lives which they exact,

they impair its efficiency by enfeebling the health of its human population. Their direful influence is more pronounced in the tropics, whence it has been most commonly proclaimed, but our own country is by no means exempt, although its cooler climate causes it to be less severely affected.

No other insects can compete with the mosquitoes as persistent annoyers of man, and none, with the possible exception of the rat-flea, hold over him such power for evil. Practically no part of the globe that can serve for human existence is free from mosquitoes, and large areas from the tropics to the arctic are periodically invaded by them in varying abundance. Even where irrigation has made the "desert blossom like the rose" it has often also produced a crop of mosquitoes to annoy or even afflict with disease the inhabitants of the garden.

On account of their phlebotomic habits, and particularly their fondness for man, mosquitoes have always been heartily detested, even by the entomologist, and only their known association with human diseases has brought them to the serious attention of zoölogists. With this incentive, however, a vast amount of work has been done by entomologists and medical men and an enormous mass of literature has been produced in less than two decades, bearing on every conceivable aspect of the subject. We now know that mosquitoes are responsible for many deaths, much human misery and great economic loss through their activity as disseminators of malarial fevers, yellow fever, dengue fever, filariasis, etc.

In all of this, several of the more important relations of mosquitoes to public health stand out very clearly. They are: (1) Some very important diseases of man are transmitted by certain specific mosquitoes, the latter being absolutely necessary for the continued existence of these diseases. (2) The disease-bearing mosquitoes are most widely distributed in the tropics, whence they extend into portions of the temperate zones. (3) The range of mosquito-borne diseases is not necessarily coextensive with the distribution of their insect carriers, but is dependent upon other factors as well.

(4) Mosquito-borne disease may be combated either by the elimination of the mosquito responsible; by the protection of the population from its bites; by the careful screening of human patients to prevent them from infecting mosquitoes; or by a medical prophylaxis or immunization of the susceptible population. (5) Remedial measures are preferably applied against only the specific mosquitoes responsible, not against mosquitoes in general. The last is primarily a matter of economy, that the most vital needs of the community be

Fig. 1. Distribution of Malaria in the United States. (After Trask.)

first fulfilled; often more willingness on the part of the community is evinced to coöperate in fighting the most annoying or abundant species of mosquitoes rather than the ones most deleterious to the public health.

Of these methods, the first has proved the most generally applicable, preferably combined with the second and third. The last has not proved generally suitable even with malaria, where quinine is a specific remedy, or with plague, where immunization is possible.

One of the best known insect-borne diseases, and one which is of great importance in many parts of our own country is malarial fever, variously termed ague, chills and fever, etc. This was the first human disease traced directly to insect carriers and gave the impetus which has led to the unraveling of the facts connected with other insect-borne diseases.

The protozoan blood parasites that cause malaria were first demonstrated many years ago, in 1880, by a French surgeon, Laveran, who discovered them in the blood of persons suffering from malaria. Five years later an Italian, Golgi, distinguished three kinds, each associated with one of the more familiar types of malaria. They were found to go through a regular life cycle in the red blood corpuscles and, from analogy with other known Protozoa, it was suspected that in addition to their non-sexual generations in the human blood there must be a sexual development in some cold-blooded animal. Manson was led to suspect that some insect might be the secondary host and, working on this hypothesis, Ross in India first found the malarial parasites in a certain kind of mosquito in 1898. He had worked for nearly three years on a common mosquito belonging to the genus Culex without result, but finally in a mosquito of the genus Anopheles was able to trace the development of the parasite. His epoch-making discovery has been since amply confirmed and extended by experimental proof till we now know that the various types of malarial blood parasites complete their life-cycles in anopheline mosquitoes, the latter acting as the sole carriers of the disease.

The details of growth and development of these parasites, which belong to the Protozoan genus Plasmodium, are extremely interesting, but far too complicated to discuss briefly. In general it may be said that the blood of persons suffering from malaria contains the parasitic organisms, and that these, on being taken into the stomach of the proper kind of mosquito, undergo certain changes and later penetrate the wall of the stomach to form vesicular swellings. Within these they multiply, and finally on the bursting of the nodule are set free in the body cavity and find their way to the salivary glands. After becoming infected, a period of twelve to twenty days is required for these changes in the mosquito. Then for a period of several weeks the virulent organisms remain in the salivary glands and if the mosquito bites a second person the parasites are introduced with the salivary secretion,

through the puncture, into the circulation. Here they multiply and produce another case of human malaria, which develops from ten days to three weeks after inoculation.

As previously stated, only certain mosquitoes can transmit malaria, for when the parasites are ingested by other species of mosquitoes they do not continue their development, but die without passing through the stomach into the salivary glands.

At the present time malaria in its several forms is the veritable scourge of the tropics. It also extends generally into the

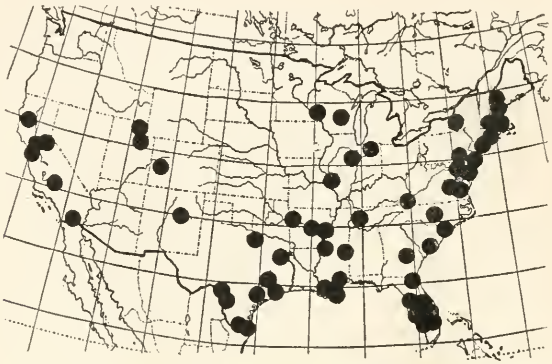

Fig. 2. Distribution of Malarial Mosquitoes in the United States.

subtropics and warmer temperate regions and is prevalent over a considerable part of the southern United States. In these areas, as appears from investigations of the U. S. Public Health Service, its range is roughly coincident with the moist austral zones east of the 100th meridian as defined by Merriam. Aside from this main area, there is a small one in southern New England and another in central California; there are also a few isolated localities scattered through the country where malaria is thought to be endemic (Fig. 1). At least three species of Anopheles are known to act as carriers of malaria in the United States and, from data given by Howard, Dyar and Knab (Fig. 2) the distribution of these taken together corresponds closely with that of malaria, although slightly more extensive, especially along the Atlantic

seaboard. As these malarious regions include a population of about 40,000,000 people, it will be seen that the importance of malaria from the standpoint of public health is very great indeed. It must be remembered, however, that the incidence of malaria varies widely, being greatest in the large southeastern area, and very much less in the more densely populated northern district. Thus in Mississippi about 80 cases of malaria per 1,000 of population were reported during the last year, or 158,000 for the entire state. Other southern states do not report the disease so thoroughly and it is difficult to estimate to what extent they are affected. It would seem, however, that one million cases each year would be a conservative estimate, especially as von Ezdorf found in a portion of one mill town in the endemic area that over 13 per cent, or one person in seven, harbored the malarial parasite in the blood, while 233 out of 500, or nearly 50 per cent, reported having had chills and fever during the summer preceding his examination. Although the death rate from malaria outside the tropics is not very great (9 per 1,000 calculated on the data for Mississippi cited above) it is by no means inconsiderable in the mass. On the other hand, the economic loss is enormous, due to inability to work during the acute attack of the fever and due to a loss of efficiency during prolonged periods following. That malaria responds quickly to anti-mosquito work and quininization is shown by the result following an application of these measures to the mill town mentioned. Referring to von Ezdorf's report, Trask says: "Measures were inaugurated to get rid of mosquito-breeding places and the use of quinine was encouraged. A year later the town was again visited and the blood of 780 persons examined. Of these only 35, or 4.5 per cent, showed infection. The health officer reported at this time that his visits among the mill employees for several months had averaged not over one a day, and that many of these were undoubtedly for old infections lasting over from previous years. The malaria rate had continuously decreased during the months when it was usually at its worst. The health officer

of the town in his report for 1914 stated that while during the summer of 1913, prior to antimalarial work, the mills were constantly short of help on account of the large numbers of employees sick with malaria, during the summer of 1914 there had not been a day when the mills did not have sufficient help. The manager of one mill stated that the improvement in the regularity and efficiency of the employees had been such that the amount ($1,000) which the mill had contributed to the fund for anti-mosquito work was more than regained in one month's operation."

While these conditions are those of one of the most severely affected districts, they are nevertheless repeated very generally throughout the entire area, more especially in the lowlands, for the hilly or mountainous and better-drained sections suffer less.

As mentioned above, several species of Anopheles mosquitoes are concerned in the transmission of malaria in the United States. Till very recently only one species, *Anopheles quadrimaculatus*, has been thought to be of much importance. Recent studies by Mitzmain and others show that this mosquito is the most important, as it may harbor the parasites of all three types of malaria, but *Anopheles punctipennis* (Fig. 3), a common, widespread species and *Anopheles crucians*, a species abundant along the eastern coast of the United States, may serve both as hosts for the tertian and estivo-autumnal or subtertian forms. The ease and frequency with which *A. punctipennis* may become infected seems to vary greatly under different conditions and its importance at least in northern districts is by no means proved.

All three species readily enter houses and are persistent biters, although no more so than some other mosquitoes. Both *quadrimaculatus* and *punctipennis* breed in stagnant water, usually that of permanent nature containing algæ or other plant growth. They commonly occur near together, with *punctipennis* usually more abundant. Larvæ of the latter species occur also rarely in temporary puddles and both

are occasionally to be found in the growth along the sides of slowly flowing streams. The breeding grounds of *A. crucians* are mainly restricted to regions adjoining the salt and brackish marshes along the coast, although the larvæ are most abundant in fresh water. The two Anopheles occurring on the Pacific coast region, *A. pseudopunctipennis* and *A. occidentalis,* have habits similar to those of *quadrimaculatus,*

Fig. 3. *Anopheles punctipennis,* female.

although the second species breeds in brackish waters also. As is the general habit among adults of Anopheles, these mosquitoes feed mainly at twilight and malaria is acquired only by persons who expose themselves to their bites after nightfall. Occasionally they bite during the daytime, but as malaria appears never to follow such bites it seems probable that only newly emerged females and consequently non-infected ones bite at this time, as is the case with the yellow-fever mosquito.

Like other insect-borne diseases, malaria shows in its seasonal prevalence a close relation to the seasons (Fig. 4), undergoing a period of quiescence during the winter and attaining a sudden maximum in late summer, after which it rapidly declines. This is in response to the increasing abundance of Anopheles during the summer, coupled with a

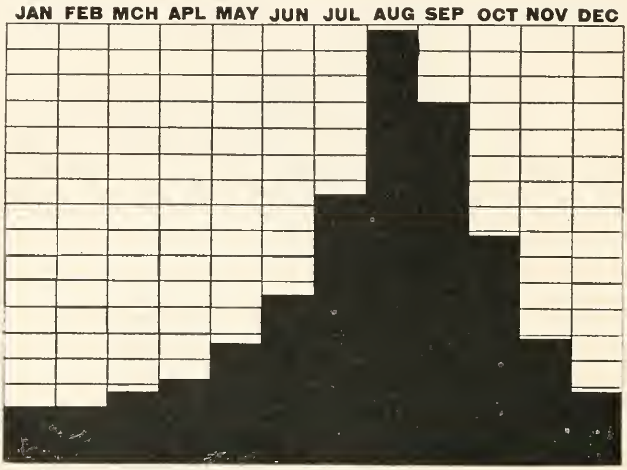

Fig. 4. Seasonal Prevalence of Malaria in the United States.

relatively high temperature, favorable for activity on the part of the mosquito and for the development of the malarial parasites in its body. It has recently been clearly shown by Mitzmain that under the conditions of temperature prevailing in the United States the malarial parasites do not persist through the winter in hibernating mosquitoes, but winter over in the human host from whence the Anopheles secure them the following season.

The larval or preparatory stages of anopheline, and of practically all other mosquitoes, are passed in the water of small quiet ponds, puddles, exposed vessels containing water, rain barrels, etc., and it is during this period that they are most easily controlled. This is accomplished by oiling the water with either crude or refined petroleum or with some miscible oil. The petroleum forms a film over the surface of

the water through which the larvæ can not extrude their breathing tubes and they are thus suffocated. The application of miscible oils is efficacious, but attended with some danger, since it destroys fish and predatory insects which are themselves some of the most important natural enemies of mosquitoes. Very frequently even oiling is not necessary, as much swamp land may be permanently freed from mosquitoes by very simple systems of drainage ditches which prevent the accumulation of the stagnant water in which the larvæ occur.

As pointed out, the reduction of malaria in communities is permanently accomplished most readily by the application of anti-mosquito measures, aimed mainly at the breeding-places of Anopheles mosquitoes. Such work is being extensively carried on by the U. S. Public Health Service, by other federal bureaus, by many state boards and commissions, and by certain private or semi-private institutions in widely scattered parts of the country. Through their individual and collective efforts an enormous amount has been accomplished, although painfully little in comparison with what could well be spent upon the problem, which is without question one of the great public health problems in the United States at the present time.

Another mosquito-borne disease which has aroused more interest in America on account of its spectacular appearance and higher mortality is yellow fever. This is due to a filterable virus, concerning the nature of which we can only speculate at the present time, although enough has been ascertained through experimental work to demonstrate that the virus is a living organism which undergoes a development of definite periodicity in mosquitoes of a single species known as *Stegomyia fasciata*. This mosquito enjoys a very wide distribution in many parts of the world, mainly in the tropics, but also extends into the warmer temperate regions. Yellow fever is not so extensively distributed, being absent in many places where Stegomyia occurs, but it is nevertheless present in many parts of the tropics in both hemispheres and all that is

necessary for the development of a possible epidemic in a region where Stegomyia occurs is the introduction of a human case in the early stages of the fever.

The larval habits of Stegomyia are in quite marked contrast to those of Anopheles. The adults are strictly domestic mosquitoes and occur almost entirely in the neighborhood of human habitations. Their larvæ occur in the same places, breeding preferably in vessels containing small amounts of water, rain barrels, cisterns, stray tin cans filled with rain water, etc. On this account, extermination work against the yellow-fever mosquito resolves itself mainly into the examination and treatment of cities, towns, and the immediate environs of smaller settlements.

A Stegomyia feeding upon the blood of a person suffering from yellow fever becomes infected only during the first three or four days after the onset of the fever; later than this mosquitoes do not obtain the virus. An incubation period of at least twelve or fourteen days in the mosquito is now necessary before the mosquito can infect a second person, after which the Stegomyia remains infectious for a long period and may be responsible for a series of new cases. These facts were first discovered during the summer of 1900 by a Yellow Fever Commission consisting of Drs. Reed, Carroll, Lazear, and Agramonte, of the U. S. Army. Two of these men, Carroll and Lazear, allowed themselves to be bitten by infected mosquitoes. Lazear died from a severe case of fever contracted during the course of the experiments, and Carroll nearly succumbed to a severe case following the bite of an experimentally infected mosquito.

Little further has since been learned of the etiology of yellow fever, but wonderful strides have been made in the application of these simple facts for its eradication. In Cuba, where the commission conducted their investigations, the first attempts were made, and in 1902 yellow fever had been entirely eliminated in Havana. Other West Indian islands were formerly badly infested with yellow fever, but at the present time there is little more danger from this disease

there than in the United States. Rio de Janeiro was once a hot-bed for yellow fever, but it too yielded to the destruction of mosquitoes and the screening of patients, till after a six years' fight, the fever vanished. Still more remarkable are the results accomplished in the Panama Canal Zone under the direction of Colonel Gorgas. Here the warfare against yellow fever has gone hand in hand with anti-malarial work

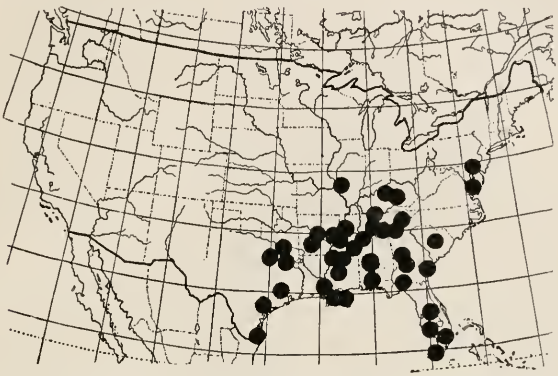

Fig. 5. Distribution of the Yellow-fever Mosquito in the United States.

and the isthmus has been transformed from a veritable death-trap to a condition which compares favorably with that of any region on earth.

Our own country has suffered from yellow fever in the past, mainly in the south, but extending to southern Illinois in 1878, to Philadelphia in the terrible epidemic of 1793, and even to Boston and into interior New England towns in the earlier days.

Yellow fever no longer causes serious concern to residents of any part of the United States, or, for that matter, to those of most parts of the American tropics. Most of us can recall very clearly in the not far distant past, however, the terror and demoralization which accompanied its periodical appearance in our southern ports. The yellow-fever mosquito is still abundant and widely distributed throughout the southeastern states (Fig. 5) and sometimes becomes temporarily established further north during the summer.

There is no yellow fever, except an occasional stray case from the tropics, which does not get beyond the keen eyes of the Public Health Service, and consequently our population of yellow-fever mosquitoes remain free from the dread disease. In this case several factors have combined to make possible the elimination of the disease without more than temporary and local eradication of the mosquito. In our southern states the disease does not easily survive the winter and chronic human carriers do not exist, so that past outbreaks have been due to fresh introductions and have been terminated by cold weather. During the last epidemic that occurred in New Orleans, in 1905, vigorous anti-mosquito measures were necessary, but, due to the greater severity of the disease, the consequently greater ease with which it is recognized, the limited area to be dealt with, and the absence of chronic human carriers, the eradication of yellow fever without permanent mosquito repression has been easy in comparison with the control of malaria. The success of this campaign has undoubtedly sounded the death knell of the yellow-fever epidemic and panic in the United States, for New Orleans has amply demonstrated what may be accomplished in the control of an epidemic by an efficient group of workers, backed by a sympathetic public and supplied with reasonable funds. Even in parts of the tropics where it persists throughout the year, it is being rapidly and permanently eliminated. Indeed it bids fair to be the first disease actually to become extinct as a direct result of human discovery and applied science. What a refreshing contrast to the fate of the American pigeon and the forlorn remnants of the American bison!

Another tropicopolitan, semi-domesticated mosquito extends quite widely into the warmer parts of the United States (Fig. 6). This is *Culex fatigans*, now known as *Culex quinquefasciatus* (Fig. 7), responsible for the transmission of dengue fever or "break-bone fever." Dengue is a mild (i.e., nonfatal) disease which causes great distress and temporary disability. It is therefore a factor contributing to lack of efficiency and goes hand in hand with malaria in this respect.

Like malaria, dengue is tropicopolitan in range, and extends only into the warmer parts of the south. Here it sometimes appears in extensive epidemics, but in a much more erratic way than malaria, which has the well-deserved reputation of appearing year in and year out in the same districts. This difference is probably due to the absence of chronic human

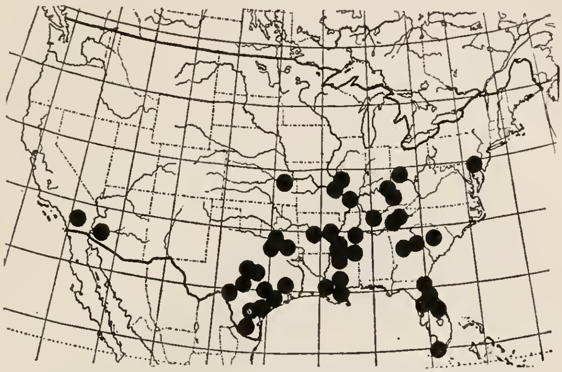

Fig. 6. Distribution of *Culex quinquefasciatus* in the United States.

carriers and the fact that *Culex quinquefasciatus* does not breed in permanent water, but is an almost truly domesticated species which breeds in temporary water near human habitations, and under the climatic and other conditions of our country does not find anything like uniform opportunities for breeding from one season to another. In consequence of their separate breeding grounds, measures designed to control malarial mosquitoes have no effect or practically none upon the dengue mosquito. It must be dealt with mainly by education leading to individual effort and coöperation in communities. Aside from its pathogenic possibilities, this species is a rather persistent biter, which is another argument for its control.

The same *Culex quinquefasciatus* has been shown to be at least partly responsible for the transmission of a parasitic disease of the tropics known as filariasis. The direct cause is a nematode worm belonging to the genus Filaria which is present in the circulation and lymphatics of the infected

person. In the late stages of the disease the microscopic larval worms occur abundantly in the blood. For some unexplained reason they remain in the deep-seated blood vessels during the day, but usually appear more abundantly in the peripheral circulation during the night. Here they are readily obtained by mosquitoes with their meal of blood. In the

Fig. 7. *Culex quinquefasciatus*, female.

alimentary canal of the mosquito the larval Filaria discards a sheath-like envelope which has previously invested it, and works its way through the wall of the stomach into the thoracic muscles where it increases greatly in size and finally migrates to the base of the proboscis. From two to three weeks are necessary for this metamorphosis, and for some time longer the Filaria may remain in the proboscis awaiting its opportunity to enter another person through the wound occasioned by the mosquito's beak. Once they have been transferred to their human host, the parasites enter the lymphatics where they attain sexual maturity and give rise to the abundant microscopic larval Filarias that reënter the circulation to await ingestion by another mosquito.

Filariasis is most common in equatorial regions, but extends less commonly into the subtropics. The parasites themselves do not ordinarily cause great inconvenience, but their presence in the lymphatics may clog these vessels and large swellings developing in the limbs or other parts of the body are thought to be sequelæ.

Less directly detrimental to public health are other mosquitoes not associated with any human disease, but making life miserable at some season of the year for human beings in practically all parts of the world. Although the United States supports an extensive mosquito fauna, a very few species aside from those already mentioned make up the bulk of those annoying man. Two in particular are widespread, abundant, and on account of their strikingly different habits, perhaps worthy of mention in this connection. The first of these is the house mosquito, *Culex pipiens*, a palearctic species, now common throughout the eastern states, that breeds in rain barrels, cesspools, sewer catch-basins, puddles, or practically anywhere, no matter how foul the water. The other, *Aëdes sollicitans*, the salt-marsh or "Jersey" mosquito, breeds only along the coast in salt marshes. Broods of this mosquito follow the lunar calendar, developing after the high tides flood the meadows and fill the pools in which the larvæ live. The eggs of this form are laid on the mud and hatch quickly when submerged in water. It is generally believed that all the eggs laid by this mosquito must pass the winter before hatching and that the successive broods are only installments of eggs induced suddenly to hatch in turn by successive wettings. This is a true migratory mosquito, which invades the country for many miles adjacent to the salt marshes. Such incursions follow the appearance of each brood.

Much attention has been given to the control of this mosquito in New Jersey and the territory surrounding Long Island Sound, and its numbers have been marvelously lessened through the drainage of marshes by ditching. In the case of this species reforms have been easier than with the

malarial mosquitoes, as an expectation of relief from the great personal discomfort of myriad mosquito bites exerts a stronger appeal to the average person than the much more important health problem of malaria. In the public mind, the latter is unfortunately not usually regarded as so immediately personal, as the fever and the bite are not coincident.

At some time during the insect season, usually in the spring, many districts are visited by swarms of small humpbacked flies which viciously bite man and animals alike. On account of their dark color these have been called black flies. They pass their developmental stages almost entirely in swiftly moving brooks and streams, where the larvæ and pupæ are attached to stones and other objects in the water. Wherever there are suitable streams in which they can breed, these pests appear abundantly, and may be occasionally present far from streams, where they would not be expected. They are not known to be concerned in the transmission of any disease.

Minute flies, somewhat like mosquitoes, which are vicious bloodsuckers, often appear in great abundance, particularly in the cooler parts of the United States. These insects belong to several genera, developing from aquatic larvæ inhabiting fresh water and also brackish water along the seacoast. They are generally crepuscular, biting most abundantly at dusk, and are persistent at that time, causing a stinging sensation out of all proportion to their almost microscopic size. None of our species are known to be disease carriers.

The regions surrounding the Mediterranean Sea are the centers of distribution for a very interesting, but not dangerous insect-borne disease known as phlebotomus fever. In this case the carriers are minute gnat-like flies of the family Psychodidæ known as Phlebotomus. These insects are semiaquatic in the larval condition, occurring in damp situations, drains, cellars, etc., where they feed on plant matter. The adult is a vicious biter in spite of the fact that it is scarcely over one millimeter in length. It rarely bites except at night,

following the habits of certain mosquitoes in this respect. The specific cause of phlebotomus fever is not known, but it has been shown to be an invisible virus. At the present time it is impossible to state whether other insects may play a part in its transmission, although such does not seem probable. We have at least one species of Phlebotomus in the United States and it is possible that it might act as a vector should the disease be introduced into our country, although it would seem that such a possibility would have been realized already if it were likely to occur, for cases of this common European fever must undoubtedly have been imported.

The common housefly (*Musca domestica*) is a common agent in the spread of certain infections which are often grouped under the term of fly-borne diseases. Of these it may be urged that, strictly speaking, there are none, at least in the sense of mosquito-borne diseases. The housefly is not known to be wholly responsible for the transmission of any disease and its relative importance in disseminating several infections of man is still a moot question. By some it is strongly urged as the main means of transmission for several enteric diseases in certain communities; by others it is cast aside without reasonable consideration as a sort of entomologist's nightmare. I can not believe that either course is justified; each seems to be based on prejudice due to lack of knowledge, either respecting the fly or relating to other channels of infection.

The housefly (Fig. 8) is more truly domesticated than any other insect; it lives and flourishes wherever man establishes himself, but does not thrive elsewhere. It has evidently been associated with him from the remotest antiquity, but has by no means failed to adapt itself to changed conditions. It still develops in the animal and vegetable refuse which accumulates about his habitations and still invades his dwellings to partake of his food. In short, it is practically ever-present, for its preferred larval food, horse manure, is usually to be found, and, if not, substitutes are available in greater or less abundance.

Several other species of flies appear regularly in houses, but in far lesser numbers, and none exhibit to such a marked degree the peculiar tastes of the housefly, which wanders back and forth from filth to food, feeding on each in turn. In this method of feeding lies the danger of infection by houseflies; they are equally fond of clean and filthy materials, and their frequent migrations from one to the other multiply

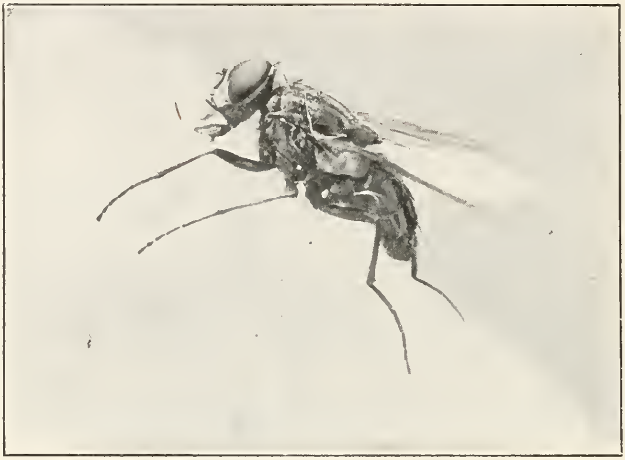

FIG. 8. Housefly, showing method of feeding.

their opportunities to pick up pathogenic organisms that may be later deposited upon foods. The frequency with which this actually happens is of course the vital point, and it is upon this that it is very difficult to obtain concise data.

It has been shown rather conclusively that adult flies do not retain in the alimentary tract bacteria which they may have ingested as larvæ that have developed and fed in material containing, for example, the bacillus of typhoid fever. On the other hand, adult flies readily obtain this bacillus from contaminated substances and may retain and later deposit it in a living condition on food designed for immediate human consumption. There can be no question but that this occurs commonly under many circumstances, particularly in communities where there is no adequate system of sewage dis-

posal. That these bacteria should be more attenuated than those occurring in drinking water does not seem probable. Many facts show that flies are a very important factor in the dissemination of typhoid fever. The greater frequency with which persons on country vacations contract the disease is very striking, although this may, of course, be attributed to bad water supply. Other opportunities for infection, aside

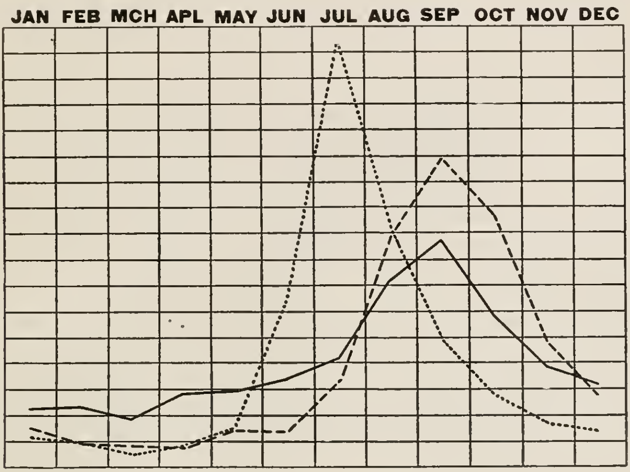

FIG. 9. Seasonal Prevalence of Typhoid Fever in Several States; solid line, New York; dotted line, Alabama; dashed line, Washington.

from the fly, are, however, no greater there than in the city. In other parts of the world where the water supply is reasonably good, e.g., certain South American cities, typhoid flourishes to an alarming extent, due undoubtedly to excessive soil pollution, where flies can almost instantly transfer material from typhoid carriers to food, while the latter is abundantly exposed on the streets for sale to be eaten on the spot. In our own country the seasonal incidence of typhoid fever corresponds to some extent with fly prevalence, and still more significant is its greater summer prevalence in regions where systems for sewage disposal are not generally installed. This disparity is shown on the accompanying chart (Fig. 9,) which gives data for two of our eastern states, New York and

Alabama, and one western state, Washington. The greater uniformity throughout the year in New York, where the opportunities for fly-borne infection are curtailed, is very marked. Another way in which the housefly can aid in the spread of typhoid is through infecting milk on dairy farms where carriers are present and offer the flies a chance to become infected.

Flies are also responsible, and to a much greater extent, for the prevalence of infantile diarrhea or summer complaint, and here their relation is very easily seen.

Other activities of houseflies detrimental to public health are of far less importance, but by no means negligible. They can carry the eggs of parasitic worms as well as many bacteria and other microörganisms present in the several types of unsavory food upon which they feed indiscriminately.

Recently much progress has been made in methods of abating the housefly nuisance. It has been found by workers in the Federal Department of Agriculture that certain substances, notably borax, hellebore, and a fertilizer consisting of calcium cyanamid, acid phosphate and kainit, are highly destructive to fly-larvæ in horse manure (whence the great majority of our houseflies come) and that these substances do not ruin the manure for agricultural purposes. Practical traps whereby fly-larvæ in stored manure may be caught and destroyed before transformation have also been devised. Richardson has shown that housefly larvæ can develop only in alkaline material, and some substances may thus be acidified to eliminate them as larval food.

The people of the United States spend great sums of money for fly-screens, fly-paper, fly-swatters and fly-traps and suffer much sickness and death as a result of the ubiquitous housefly. As yet no great reduction of houseflies has been accomplished, but the public regards them less and less as harmless creatures, and should soon be in the proper mental state to launch a decisive campaign against them.

Cattle, horses, and other domestic animals, and more rarely man himself, are troubled in nearly all parts of the world by a

small blood-sucking fly resembling the housefly in size and general color (Fig. 10). On account of its great abundance about horses and cattle it has been termed the stable-fly, although its larvæ breed mainly in fermenting vegetable material rather than in manure. The adult flies readily bite human beings, particularly in damp weather, and this habit has given rise to the popular idea that houseflies bite before

FIG. 10. Stable-fly (*Stomoxys calcitrans*).

a shower. The stable-fly is most important as a pest of animals, as it has not been definitely proved to be more than an accidental carrier of any disease affecting man. It was at one time thought to be a carrier of poliomyelitis (infantile paralysis), but it now seems probable that such is not the case.

One of the most important insect-borne human diseases which does not exist in the new world is African sleeping sickness. In recent years this malady has decimated the native population in certain parts of eastern equatorial Africa and any extension of its range would be most serious. It seems very unlikely that America will ever have to face an epidemic, for the introduction of sleeping sickness together with its carriers is not at all probable, and the possibility of its becoming established, even after introduction, is still

more remote. As is well known, sleeping sickness depends for its spread entirely upon certain biting flies known as

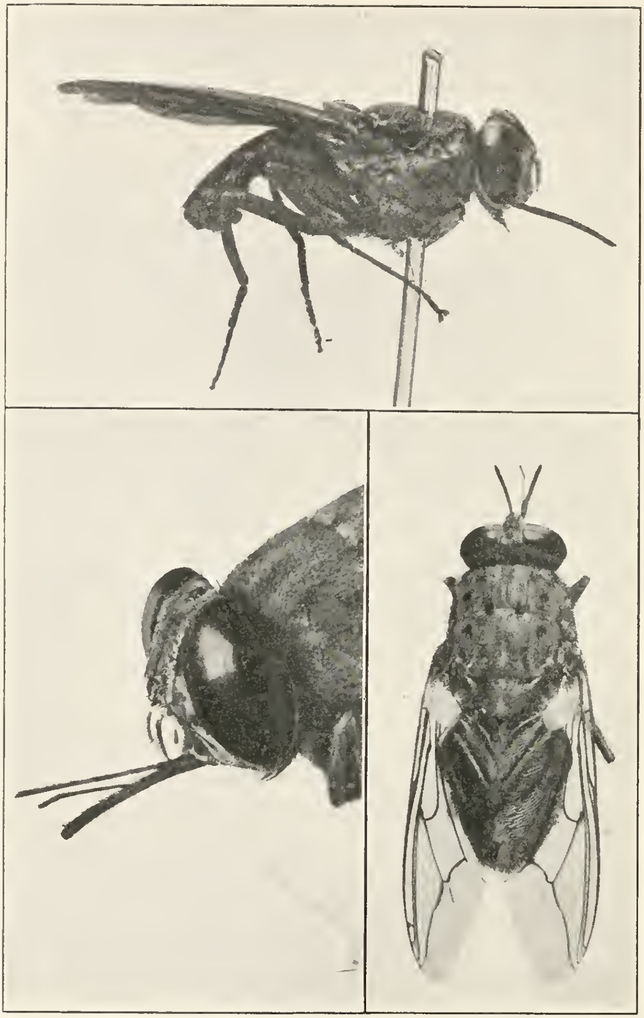

FIG. 11. Tsetse-flies. Above, *Glossina palpalis,* the carrier of human sleeping sickness; below another species of Glossina with a more enlarged view of the head and blood-sucking mouth parts.

tsetse-flies belonging to the same family as our common house-fly and stable-fly. The genus Glossina (Fig. 11) in which

these flies are included, is restricted to the African continent, but is there represented by a number of species, several of which have been shown to act as carriers for trypanosome diseases in animals. One only, *Glossina palpalis,* carries the common trypanosome of human sleeping sickness, *Trypanosoma gambiense.* The disease appears to have been originally endemic only in West Africa, but was found in eastern equatorial Africa something over fifteen years ago, and it is in this latter region that its ravages have been so pronounced. Owing to certain peculiarities in the habits of the tsetse-flies, the distribution of sleeping sickness is limited to very definite areas in the region where it occurs. The fly, which has a sharp needle-like beak for sucking blood, resembles our own stable-fly (*Stomoxys calcitrans*) in general appearance but is considerably larger, measuring about half an inch in length. It is found only in the dense brush which grows along the edges of streams, ponds and lakes. In such places persons and animals may be bitten by the flies and it is exclusively through such bites that these insects may obtain virus of sleeping sickness from the blood of a person or animal suffering with the disease. Should the fly obtain a meal of blood containing trypanosomes, these may multiply in the body of the fly, although not always, for only about one in twenty of such flies becomes infectious. A considerable period must now elapse before the infected fly is in condition to inoculate a new patient, usually thirty or forty days, but after this for at least seventy-five days it remains infectious, and may introduce the trypanosomes into the blood of any animal upon which it feeds during this period.

The tsetse-flies develop in a very different way from most insects. The female does not deposit her eggs, but a single one develops to the fully grown larval condition before being deposited. This larva soon pupates in the shade beneath the brush bordering the water where it has been dropped by the parent fly, and later emerges in the winged adult condition. The pupæ require such moist shade, and it is apparently for this reason alone that the flies never occur away from the

immediate vicinity of the water. As a result of their method of development, the tsetse-flies do not multiply rapidly, and under favorable conditions only one larva is produced in a ten-day period.

The trypanosome of sleeping sickness was discovered by Bruce in 1902 and a year later the rôle of *Glossina palpalis* in its transmission was proved. Since then much energy has been expended in attempting to stamp out the disease by every possible means. It was thought at first, that by moving all the natives back from the edges of the water the flies thus left without opportunities for reinfection, would become free from trypanosomes, and that by isolating and treating cases of the disease in fly-free areas it would be possible to eliminate it entirely. In conjunction with this, the cutting of brush, especially about boat landings and watering places, has been practised as far as possible. Contrary to expectations, it has been found that even after three or four years, infected flies still occur along the uninhabited shores. This led to experimentation upon animals and it is now known that various wild antelopes as well as certain domestic animals may act as reservoirs for the virus of sleeping sickness which may thus persist in the complete absence of any human subjects. As a result of this discovery the great difficulties of combating the disease among the ignorant African natives have been vastly increased.

Louse-borne diseases have come into prominence during the recent war in Europe on account of the prevalence of typhus fever in Serbia and certain parts of the eastern war-front. Typhus fever has been known to be conveyed by lice for a number of years, but the association of these insects with trench fever was proved only during the latter part of the war, and their rôle as carriers of a certain type of relapsing fever is also a quite recent discovery.

Human lice, or cooties, to use their most recent nickname, belong to three species, two known respectively as the head and body louse (Fig. 12) (*Pediculus humanus* and *P. corporis*), and the third as the crab louse (*Phthirius pubis*). All three

are strictly human parasites and do not occur upon any other animals. Only the body louse appears to act as a carrier of the louse-borne diseases.

Typhus fever has been well known for many years and regarded as a disease characteristic of filthy surroundings.

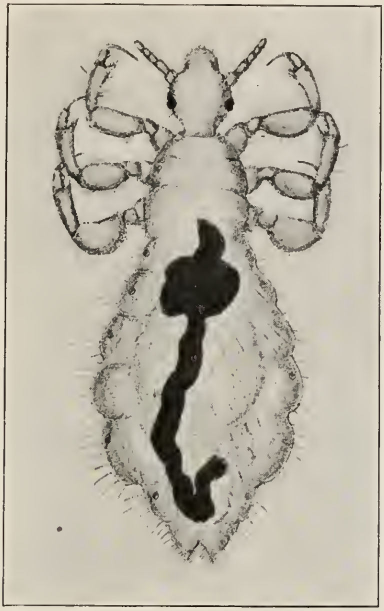

Fig. 12. The body louse (*Pediculus corporis*).

During our own civil war it claimed many victims among the inmates of army prisons, and has been endemic though not very prevalent in many parts of the world in times of peace (Figs. 13a & 13b). Through the researches of Ricketts and others we know that typhus is spread by the body louse and its epidemiology is at once made clear. When it broke out in Serbia in 1915 in severe epidemic form, a knowledge of the method of its transmission made control possible, even under extremely difficult and unfavorable circumstances.

Trench fever has attracted notice in the European war zones, to which it appears to be restricted so far as present knowledge extends. That it is a new disease is, however,

without question an utterly unwarranted assumption for it has undoubtedly been brought to Europe from some little-known quarter of the globe, unless it may have previously existed in Europe which does not appear probable. During the later part of the war it was successively recognized as a distinct disease, suspected of association with the louse, and soon proved actually to be louse-borne. We now know that

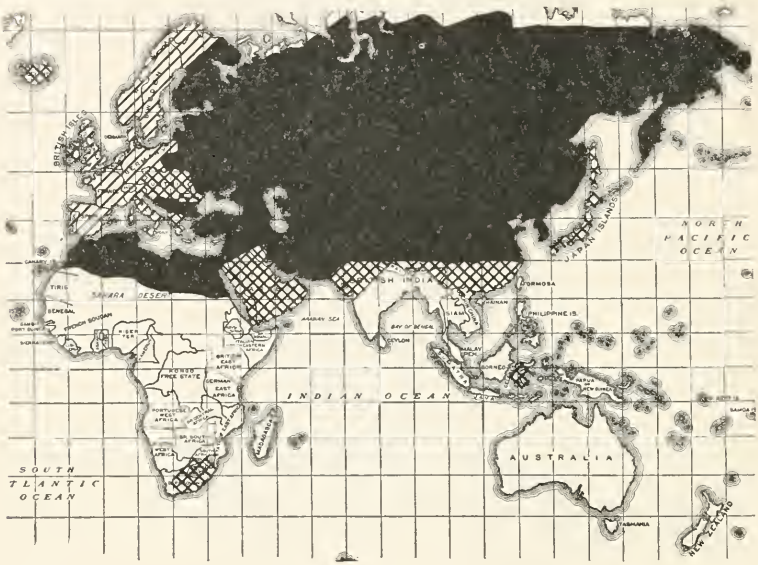

Fig. 13a. Map illustrating the distribution of typhus fever in the old world. It is a common disease in the regions marked with black, less common in those marked with cross-hatched lines and rare in those marked with parallel lines. (After Byam, *et al.*)

the disease is due to a living microörganism probably of such small size that it cannot be recognized under the microscope. This virus is obtained by the lice with their meal of blood taken from an infected person. At least five days must elapse before the louse becomes capable of transmitting the disease, indicating that the organism must undergo a development of definite periodicity in the insect. If it is transferred to another person its bite is not or only rarely infectious, but its excrement contains the virus and if scratched into the skin, trench fever develops. Typhus fever is a very danger-

ous disease with a quite high death-rate, but trench fever is non-fatal and its importance in the war zones has been due

Fig. 13b. Map illustrating the distribution of typhus fever in the new world. It is a common disease in the regions marked with black, less common in those marked with cross-hatched lines and rare in those marked with parallel lines. (After Byam, *et al.*)

to its great prevalence and the fact that persons affected with it are incapacitated for extended periods.

The louse is also responsible for the spread of relapsing fever in Eurasia, North America, and northern Africa. This

disease is endemic over very extensive areas and is a common malady in the Old World. In Africa a different form of relapsing fever is carried by a tick (*Ornithodoros moubata*) and ticks are also thought to convey it in South America. For a long time ticks were believed to harbor both types of relapsing fever, but recent researches have disproved this idea.

Rocky Mountain spotted fever is the only definitely characterized tick-borne human disease that occurs within

Fig. 14. Rocky Mountain Spotted-fever Tick, male at left. Unengorged female at right.

the confines of the United States. In 1902 Wilson and Chowning suggested that ticks might carry this disease, and four years later Ricketts definitely proved such to be the case. Rocky Mountain spotted fever is restricted to the far western and northwestern states, whence 290 cases were reported during the year 1916. Over half of these occurred in Idaho, although the disease extends into the neighboring states of Montana, Wyoming, Colorado, Utah, Nevada, California, Oregon, and Washington, as well as northward into Canada. As shown by the fatality rate, the disease is most virulent in western Montana and northern Idaho, where the mortality is said to reach 70 or 80 per cent. A single species of tick, *Dermacentor venustus* (Fig. 14), common in these regions is known to act as the vector. The Dermacentor ticks occur abundantly on various small wild mammals

in the younger stages and as adults on domesticated animals, such as cattle, and from these become transferred to man. It has been experimentally shown that certain rodents are susceptible to the disease, and a tick thus infected in the nymphal stage can retain the disease organism till it becomes adult. It may then reach its human host through the medium of domesticated animals such as cattle. It appears that this is the ordinary way in which human cases have their origin, i.e., through the bites of adult ticks, although the newly hatched "seed ticks" derived from eggs laid by infected mother ticks are known to contain the organism also.

Although Rocky Mountain fever is of minor importance at present, it is feared that it may increase its range at any time, since other ticks of wider distribution are apparently capable of acting as carriers.

Whether this may happen is by no means certain, however, and the vigorous measures already undertaken to reduce the abundance of ticks on domesticated animals will undoubtedly bear fruit in the gradual reduction of this locally much-dreaded disease.

The flea is another domestic insect which was looked upon only as a nuisance until it was shown that certain kinds of fleas are agents in spreading bubonic plague. The most terrible epidemics of which we have any historical record have been those of plague, or "black death." One swept from Egypt in the sixth century before the Christian era and invaded Europe and Asia, where it raged for sixty years. A similar one spread through the whole known world in the fourteenth century and is thought to have caused over twenty-five million deaths before it subsided. In 1898 Simond suspected fleas as agents in the spread of plague and his suspicions were later proved to be true through the researches of Verjbitski and the Indian Plague Commission. Plague is primarily a disease of rats and certain other rodents, and is usually carried to man by the bites of fleas which have become infected from plague-stricken rats. From 300,000 to 400,000 cases of this disease are reported from India

every year, over half of which terminate fatally. At the present time it is most widespread and abundant in tropical countries, although by no means confined to them, and is excluded from our own country only by dint of repressive measures administered with the greatest thoroughness. Within the past few years it has appeared only sparingly in the United States, but at several times has given rise to a temporary apprehension lest it pass beyond control. That it has not done so shows the probability of future danger is remote.

Nevertheless there are other good reasons why we should spare no efforts in reducing the number of rats. They are said by Nelson to destroy annually $200,000,000 worth of our foodstuffs and other property; they constitute a fire-menace, and besides, they can hardly be considered as deserving our hospitality from an esthetic standpoint. In short, war against rats is important for many reasons, one of which is the security against plague which it entails, and gradual repression through individual effort is much easier than intensive campaigns necessitated by the advent of plague in a community.

The relation of the flea to the transmission of plague is due to the fact that rats are regularly infested by fleas that may become infected with the bacillus of plague, if it be present in the blood of the host upon which they are feeding. These bacilli remain in a viable condition for some time in the gut of the flea and may be transferred to a human subject bitten by an infected flea. Thus, when a rat dies of plague, its fleas leave it to search for a new host; if they attach themselves to a rat, that animal is liable to infection, or if they feed upon a human being, as they frequently do, the disease may become transferred to man. Two species of fleas are commonly concerned in the transfer, one in tropical and subtropical regions and another in temperate regions. The tropical rat-flea, *Xenopsylla cheopis* (Fig. 15) is thus of greatest importance in the warm countries where it is most abundant, and the other, *Ceratophyllus fasciatus* (Fig. 16), in cooler countries. Both

occur in the United States, neither specifically associated with plague except as previously outlined; other fleas may

FIG. 15. Tropical Rat-flea (*Xenopsylla cheopis*).

act as carriers equally well, but are not so abundant on rats and do not bite persons so frequently.

The plague bacilli (*Bacillus pestis*) appear only in fleas which have bitten affected persons or rats twelve to twenty-

FIG. 16. Rat-flea of Temperate Regions
(*Ceratophyllus fasciatus*.)

six hours previous to death, for after this time the bacilli do not occur in the blood. The vitality and virulence of the

bacilli are preserved for nearly a week at least and sometimes fully a month; and there is actually an increase in their number during the first few days. Infection from these insects may then occur through their bites, if they contain extremely virulent bacilli, but probably occurs more commonly by the insects being crushed *in situ* after they have punctured the skin.

There are many reasons for believing that infantile paralysis may be an insect-borne disease, and a few words in regard to

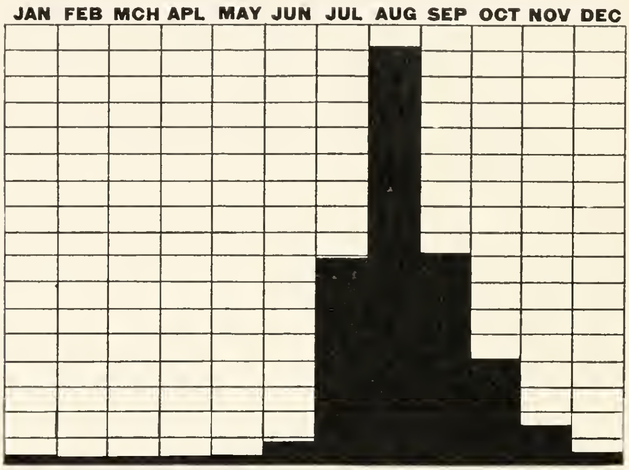

Fig. 17. Seasonal Incidence of Infantile Paralysis in the United States During 1916

this baffling disease may not be amiss. Its summer prevalence (Fig. 17) is well known and its general distribution and occurrence are similar to those of insect-borne diseases. That it may be proved to be spread by the rat-flea is not improbable, and if so, would be another strong argument for the reduction of our rat population.

No account of insect-borne diseases, however brief, could be complete without some reference to animal diseases. A few of these have already been referred to incidentally as affecting both man and animals, and it is quite likely that other human diseases whose etiology is at present obscure, will in the future be shown to bear some relation to those of

animals. Apart from this, the economic loss occasioned by such affections of domestic animals is enormous, although it is in great part preventable.

A wide-spread disease of cattle in the southern part of the United States, known as splentic fever, or "Texas fever," is the most important insect-borne animal disease that occurs in this country, and is particularly interesting since it was the first disease of any kind shown to be carried exclusively by insects or ticks. It occurs very generally throughout the gulf states as far north as the thirty-sixth parallel of latitude and is the cause of immense pecuniary loss to this region, not only on account of the cattle lost, but as a result of the greatly weakened condition of the animals in general. Southern cattle are usually immunized by an attack at an early age, but northern animals die in large numbers when exposed to the disease.

Smith and Kilborne showed in 1893, that the protozoan blood-parasite, *Babesia bigemina,* which Smith had discovered several years earlier to be the cause of the disease, is carried by ticks. The common cattle-tick of the southern United States, *Margaropus annulatus,* acts as the exclusive vector, becoming infected during its period of engorgement when feeding on the blood of a diseased animal and then transmitting the Babesia through its eggs to the young ticks of the next generation. These may feed on healthy animals the next season, conveying to them the parasites that have been handed down from the mother tick.

Several similar diseases of cattle occur in other parts of the world. In Africa, related forms of Piroplasma carried by ticks are the cause of redwater, East Coast fever, Rhodesian fever, and in various parts of the world other piroplasmoses have been observed in many animals.

Spirochætosis in animals, due to organisms similar to those producing relapsing fever, is well known. The most familiar example is probably a disease of fowls which is carried by *Argas miniatus,* a common tick which infests these birds.

Trypanosomiasis is a general term for diseases like sleeping sickness due to trypanosomes and there are many diseases of this type, among which may be mentioned an old-world affection of horses known as Surra; an African one, Nagana, that attacks other domestic animals as well; and a South American type termed Mal de Caderas. Flies are the insects implicated in the transmission of these diseases, mainly the large tabanid horse flies and the smaller stable-flies of the genus Stomoxys. Surra has been introduced into the United States, but was successfully stamped out before it had become established.

Among bacterial diseases of animals, anthrax may be mentioned as one which is sometimes transmitted by biting flies, the insects acting as mechanical or contaminative carriers only.

The foregoing enumeration of insect-borne diseases is by no means complete. Indeed, it would be well-nigh impossible to make it so, in view of the rapid strides which are being made at the present time toward a knowledge of these many problems which bear on the question of public health. New discoveries are being rapidly announced in all parts of the world, and while it is difficult to see how the fundamentally important revelations of the past twenty years can be equalled in the near future, we should be very unwise to predict that they will not be exceeded.

CHAPTER II

INSECTS AND THE FOOD SUPPLY

It is a widely recognized fact that insects consume much food material that might otherwise serve for human consumption. The truth of this assertion has been repeatedly brought home to all who have attempted in a modest way to supply their own household needs by means of vegetable gardens, as well as to those engaged primarily in agricultural pursuits. Following the spirit of the times, the home vegetable garden has become successively the war-garden and the conservation-garden, and agricultural production in America has grown apace. These immediate changes have not affected the fundamental relations existing between insects and food-plants, nor have they influenced their economic expression to any noticeable extent. They have, however, served to impress upon the entomologist his responsibility as an interpreter of insect activities in so far as these relate to the production of human foodstuffs.

The matter is far less simple than might appear at first sight. In the first place, it depends upon many of the factors which determine the so-called "balance of nature," and secondly it involves the abnormal and rapidly changing environment which has resulted from agricultural development.

The extent of the loss occasioned by insects to growing agricultural crops, and to edible products in storage, can be estimated with some degree of accuracy by persons familiar with agricultural practice and with insect depredations over wide sections of the country. Several times the Federal Bureau of Entomology has gathered together statistics which give an adequate idea of the proportion of vegetable food products actually lost through insect injury, and the consequent monetary loss to the people of the United States. From their estimates it appears that fully 10 per cent of our agri-

cultural production is annually destroyed by insects, or in other words, that our food supply from this source is only 90 per cent of that which would be available if insects were not a factor in limiting the yield. I think all entomologists will agree that this 10 per cent reduction is an under-estimate rather than an exaggeration and as the value of the products in question is roughly $10,000,000,000 it follows that agricultural insect pests rob the country of approximately a billion dollars annually. This omits, of course, such important crops as cotton, tobacco, etc., which have no food value, or of which the food value is secondary, as is the case with cotton which is grown primarily for the lint although the seed forms an important part of the rations of food animals like cattle, which are in turn utilized for human food. It includes on the other hand the loss of products in storage such as flours, meals, rice, beans, etc. The table below differs somewhat from others of similar nature that have been published, but is essentially similar, and is, I believe, as close an approach to accuracy as can reasonably be expected.

TABLE SHOWING ESTIMATED DAMAGE TO VARIOUS PRODUCTS CAUSED BY INSECTS, BASED MAINLY ON PRICES CURRENT IN 1916

Product	Value	Loss
Cereals	$4,241,000,000	$424,100,000
Hay	1,008,000,000	100,800,000
Cotton	1,066,000,000	106,600,000
Tobacco	169,000,000	16,900,000
Truck Crops	512,000,000	76,800,000
Sugars	130,000,000	13,000,000
Fruits	262,000,000	39,300,000
Farm Forests	110,000,000	11,000,000
Misc. Crops	97,000,000	9,700,000
Animal Products	4,338,000,000	433,800,000
Stored Products	219,000,000	21,900,000
Forest Products	100,000,000	10,000,000
Total	$12,252,000,000	$1,263,900,000
Food Total [1]	$9,723,000,000	$1,021,000,000

[1] Omitting tobacco, farm forests, forest product entirely, and cotton and animal products in part.

It does not take into consideration the present greatly advanced prices which are, no doubt, temporary exacerbations

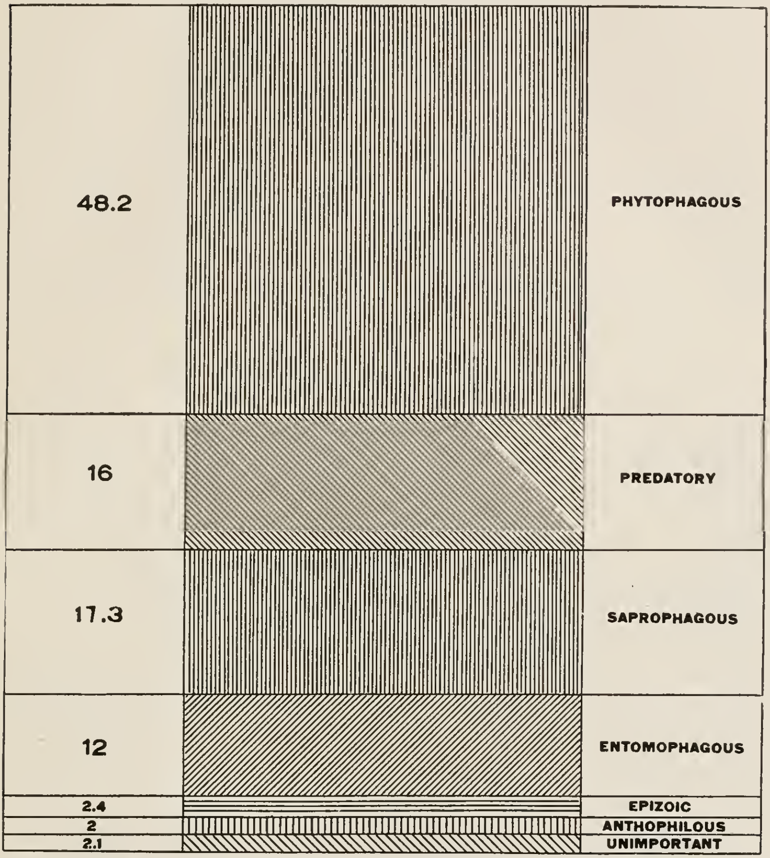

FIG. 18. Diagram illustrating the comparative abundance of various types of food-habits in insects. The figures at the left indicate the percentage of species exhibiting the several types. This chart is based on the recorded fauna of a limited area (New Jersey) which includes about 10,000 species. (Modified from Weiss.)

destined to subside, like many of the invasions of insects detailed in one of the following chapters.

When we consider that insects are, with the exception of the Protozoa and certain marine invertebrates, the most abundant animals on the earth, it is not surprising that no plants appear to be free from insect enemies. I have usually assumed that about one-half of the 450,000 described, living

species of insects were phytophagous in habits, feeding directly upon the tissues of various plants. This proportion is probably not far amiss as Weiss has recently tabulated the food habits of the 10,000 insects of New Jersey enumerated in Smith's list. He finds (Fig. 18) that 48.2 per cent of these are phytophagous; that 16 per cent are predatory, feeding mainly on other insects; that 17.3 per cent are saprophagous, living as scavengers; that 12 per cent are entomophagous parasites, developing in the bodies of other living insects; and that of the small residuum of 6.5 per cent, 2.4 per cent are epizoic parasites of vertebrates. Only 2.1 per cent appear to be of no human importance in so far as we can judge at the present time.

Of course, the great majority of phytophagous insects affect plants never or rarely utilized by man and bear no direct relation to food production. However, agricultural plants show no immunity to insect attack, but quite decidedly the opposite condition prevails, that they are more susceptible; and this is undoubtedly due to several causes which I shall attempt to enumerate.

The species of plants suitable for cultivation as sources of food, are naturally those which produce more than average amounts of food material in some part of the plant body. This may develop in the roots, as in carrots, in the stem as in sugar cane, in the foliage as in spinach, in the seeds as in beans, in the tissue enveloping the seeds as in many fruits, or more rarely in special organs. On this account alone, such plants are unusually acceptable to insects as they are to ourselves. Another reason for the great susceptibility of agricultural plants to insect injury depends upon the removal of certain barriers to insect multiplication which follow necessarily as a result of all agricultural development. Under natural conditions, plants almost always occur in complex associations of numerous species, of which one or several may be noticeably dominant, and many of these are capable of assuming a temporary dominance when for any reason the more abundant species decline. Such a stable, gradually

changing, or temporarily shifting condition is reached through the struggle for existence among the plants, and the balance of nature maintained by the action of adverse conditions in their environment, of which the insect population is one factor. So far as the insects dependent upon plants are concerned, the innovations of agricultural development represent a cataclysm in their environment. When an ex-

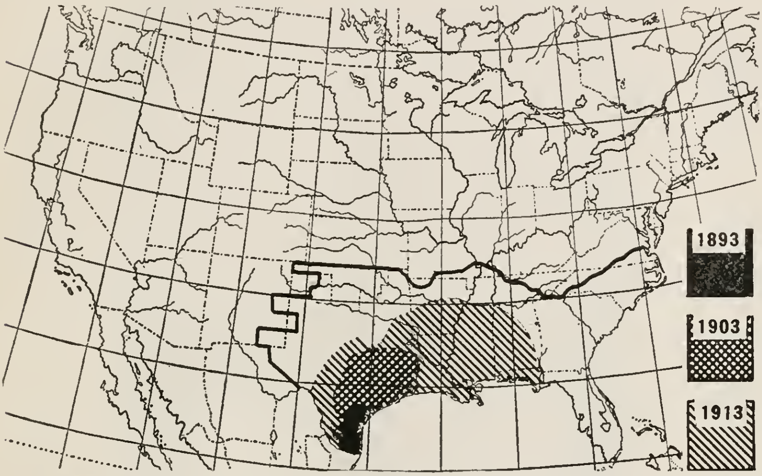

Fig. 19. Map showing the spread of the Mexican Cotton-boll Weevil (*Anthonomus grandis*), introduced into the United States from Mexico in 1892. After about thirty years it had spread over the most productive cotton growing areas of the United States; since 1913 its range has been still further extended. The limits of the cotton belt are indicated by the heavy line. (After the Bureau of Entomology, U. S. Dept. of Agriculture.)

tensive area is planted to some particular crop, three alternatives present themselves to the original insect inhabitants of the area. With their natural food plant eliminated more or less completely, they may become suddenly extinct or nearly so; this will be the fate of the great proportion and it is of practically no human concern that it is so. Others (in very rare cases, but nevertheless important ones) may turn their attention to the newly arrived plant, and find it a satisfactory substitute for their former diet. Still a third class, fortunately a very small one, will find the crop plant closely allied to, or even identical with their original source of food, and consequently acceptable to their appetites.

The proportion of these three classes of insects determine to some degree the extent of the damage which the farmer will find has been inflicted upon his crop by the end of the season.

In order to understand more fully the relations of these classes, it is necessary to inquire rather closely into the degree

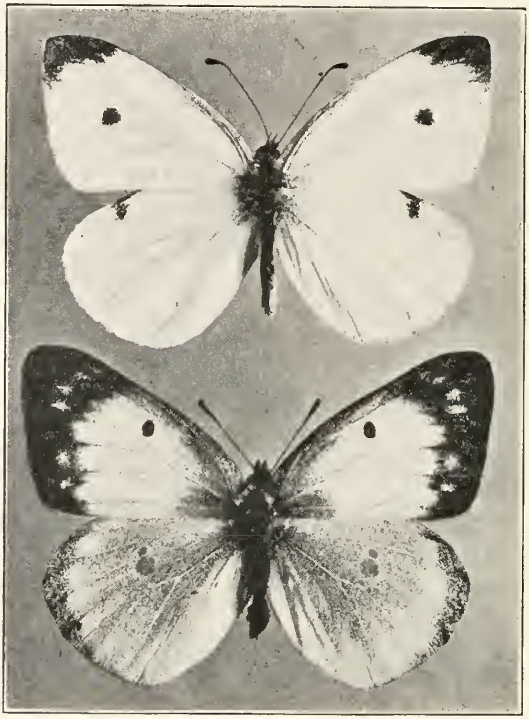

FIG. 20. The European cabbage butterfly (*Pontia rapæ*) and (below) its American congener (*Pontia philodice*). Both have the same food plants and the native butterfly has become more scarce as the naturalized species has increased in abundance.

of association exhibited by plant-eating insects to their host plants. A few insects avail themselves of very many plants as food, and such polyphagous forms like the locusts or grasshoppers, are a constant menace, whose varying abundance depends upon factors not yet mentioned. Numerous other forms which may be called oligophagous, depend upon several,

usually related, species of plants for their sustenance. Still others appear to be monophagous, or restricted to a single food plant, like the Mexican cotton-boll weevil and many others of our important agricultural insect pests.

From the agricultural standpoint, monophagous insects feeding upon the crop plants are usually the most destructive. If present in the locality where cultivation takes place, they

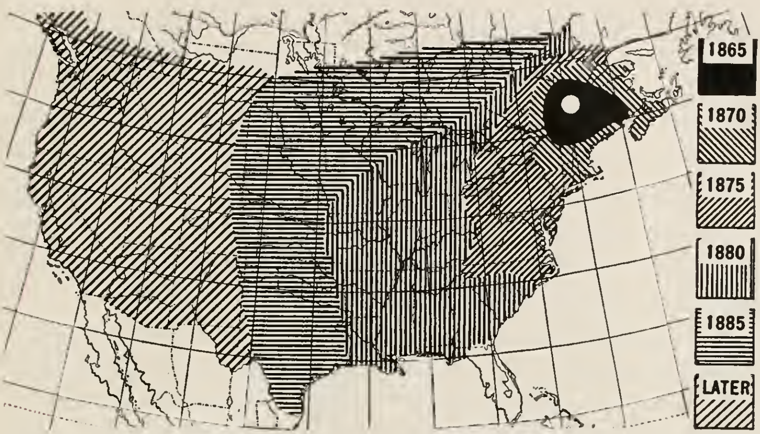

FIG. 21. Map showing the spread of the European white cabbage butterfly (*Pontia rapæ*), following its first introduction, indicated by white spot, near Quebec in 1860. This insect which spreads with great rapidity feeds in the larval state upon cabbage and other closely related plants. (In part after Scudder.)

seek out their host plant with unerring accuracy to find enormous opportunities for development and multiplication, a condition which, like the vacuum, would be abhorred by nature, but which is a corollary of all agricultural development. Further than this, the same crop is planted and carefully cultivated during succeeding years, to give never ending opportunities for increasing hordes of insects. The economic entomologist has no criticism to make of such a method of agricultural procedure, as he cannot, except perhaps within very narrow limits, propose a better one. He cannot, however, hold himself guilty when it is pointed out to him that insect ravages are constantly increasing in spite of his feeble efforts to reduce them.

The situation is still further aggravated by the constantly increasing number of foreign insects which find their way to our shores and become established to spread gradually throughout those parts of our agricultural regions that enjoy a suitable climate. Such insects, of which a very considerable number could be enumerated, are our most destructive pests. They are, of all species of animals, the most fortunate. They are suddenly dropped in the midst of plenty; they are unhampered by the enemies and parasites of their native land. That they immediately make the best of their opportunities and proceed to exploit the country is seen by the phenomenal injury done by the Mexican cotton-boll weevil or *Picudo* (Fig. 19) to the cotton crop, the gipsy moth or *Grosse Schwammspinner* to deciduous trees, the Hessian fly to the wheat crop, the cabbage butterfly (Figs. 20, 21) to various cruciferous crops, and many other naturalized insects to various other cultivated plants.

The explanation for the abnormally rapid multiplication of imported insects is not far to seek, and depends upon principles well recognized by all biologists. As was previously pointed out, approximately one-sixth of our insects are entomophagous parasites (Fig. 22), passing their developmental stages within the bodies of other living insects. Some of these parasites prey upon other parasites, but a goodly proportion affect phytophagous insects which they destroy at the time they complete their growth. Like the plant-eating forms they are restricted to definite hosts, generally few in number, with which they show a very definite association. In fact, so fixed are their instincts to restrict themselves to the same host that they ordinarily avoid any insects which they do not normally parasitize. With this in view, if we consider for a moment the conditions surrounding an insect pest introduced from another part of the world, we see that it is no longer at the mercy of the entomophagous parasites that would affect it in its native land, and that the parasites with which it is now associated will leave it unmolested. Since many of our common native insects have a dozen or more well-known

parasites which may frequently produce a death rate of from 50–90 per cent in a single season, the importance of this factor in fostering imported pests is easily realized.

A parasitic insect of this sort may be defined as one which passes a part of its developmental stages (usually the larval

Fig. 22. Two species of Parasitic Hymenoptera. Above, Dinotomus, a common parasite of butterfly caterpillars. Below, Spilocryptus; in this as in many other insects of this group, the female has a needle-like ovipositor which she thrusts into her victim to deposit her eggs within its body.

and often the egg or pupal stage also) upon or within the body of another insect or in its eggs, from which it derives its entire food supply and which it almost invariably kills before attaining its full growth. There are a great many species of parasitic insects, and there are probably very few or perhaps almost no predacious or phytophagous insects which are not subject to their attack. Even parasitic insects themselves are quite frequently destroyed by other species

known as secondary parasites, and in at least a few cases the secondary parasites are known to be infested with others known as tertiary parasites.

A parasite stands in marked contrast to a predacious species since it does not feed indiscriminately upon whatever suitable prey it may discover, but has a certain host species or series of hosts which it always selects to the exclusion of others. From generation to generation these same hosts are always chosen with most extraordinary persistence, for reasons which are at present in most cases obscure. Nevertheless such appears to be almost invariably the case, although some species of parasites have been found to attack a much larger series of hosts than others, and a very few appear to be somewhat indiscriminate in their tastes.

Parasitic species belonging to a number of the different orders of insects are known, and from our knowledge of the relationships of the different groups it is evident that the phenomenon of parasitism has arisen independently in each group, but by far the most important from an economic standpoint are those included in the Hymenoptera and Diptera. The parasitic Hymenoptera have the greater significance, and include a vast complex of species of the most varied habits, included in a long series of families. Of these the Ichneumonidæ and Braconidæ attack the larval or more rarely the pupal stages, the female ordinarily depositing her eggs within the body of the insect and the larva feeding upon the blood and tissues of its host, which it finally leaves for pupation, or destroys entirely by consuming the vital organs. In the former case, an affected larva may perhaps survive under exceptional circumstances, but ordinarily succumbs to the attack. According to the comparative size of the host and parasite, one or a series of parasites may be nourished by a single host. The members of a series of families belonging to the superfamily Chalcidoidea, which includes a vast number of small or minute species, are parasitic in habits, some of them attacking their hosts like the previously mentioned families (Fig. 23). Others present a most remarkable

phenomenon of pædogenetic, or precocious multiplication known as polyembryony in which a single egg of the parasite

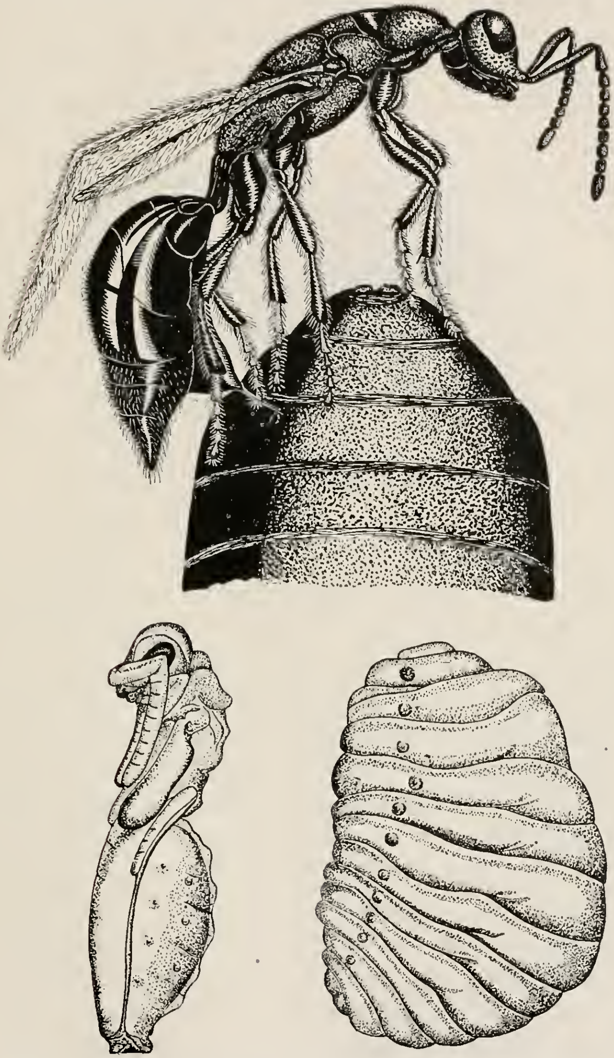

Fig. 23. A Hymenopterous parasite (*Spalangia muscidarum*) of the housefly and other related flies. The female Spalangia is shown thrusting her ovipositor into the puparium of the fly. Below are shown the larva and pupa which develop within the puparium. (After Pinkus.)

deposited in the host egg gives rise to a series of larvæ (often several hundred) which develop within the host larva. Still

other very minute species are egg parasites, completing their entire growth within the eggs of larger insects, within which the female deposits her own minute eggs. The superfamily Proctotrypoidea includes several families of minute species which are egg parasites, developing in much the same way within the eggs of other larger insects. To this group belong

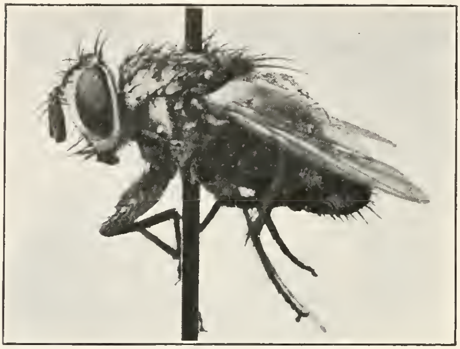

FIG. 24. A parasitic Tachina fly (*Compsilura concinnata*), an enemy of the gipsy moth.

also some other families with habits more like those of the Ichneumonidæ, which attack the later preparatory stages of their hosts.

Second in importance are a large series of Diptera belonging to the family Tachinidæ, parasitic during their larval development within the bodies of other insects, mainly the caterpillars of various Lepidoptera, although they by no means restrict their attacks to insects of this order. The Tachina flies (Fig. 24) are in some ways less specialized in their habits and as a rule do not have such definite host relations as the parasitic Hymenoptera, most species attacking a larger and more varied series of hosts. On the other hand, the methods by which the larvæ gain access to the host show highly developed adaptations. Some deposit large, oval white eggs directly upon the caterpillars or other insects within which they may develop, and the larvæ on hatching bore through the cuticle and gain entrance to the visceral cavity. Others thrust maggots directly through the skin of their victims,

while still other types deposit large numbers of minute eggs or larvæ on the foliage upon which the host insects are feeding. In the latter cases the eggs or maggots are ingested with the food, whereupon the eggs hatch and the larvæ, perforating the wall of the alimentary tract, reach the visceral cavity. One or many larvæ may live at the expense of a single host according to their relative sizes, and on attaining full growth, the larvæ usually quit the host through orifices they make in its body wall, and enter the soil for pupation, later to emerge as adult flies.

It seems probable, at least in regard to the Tachina flies, that the parasitic habit has been derived as a modification of the habit of feeding upon recently dead insects, which has been transferred to living ones and later developed its most remarkable adaptations as seen in the group at the present time. With the parasitic Hymenoptera the derivation of the parasitic habit is far more obscure, and doubtless of much more ancient origin.

Ever since scientific methods of investigation were applied to the problems of economic entomology the importance of parasites has been recognized as a factor involved in the natural control of insect pests, but it is only within comparatively recent times that their full significance has been realized. With the recent introduction of several injurious insects into our own country a minute comparison of the controlling factors here and in the country of origin has brought clearly to light the prime importance of insect parasites and attempts have been made to colonize the parasitic enemies of several pests in the United States. Similar experiments have been undertaken by foreign entomologists also, and one of the most extensive yet well under way is that aimed at the control of the gipsy moth which is discussed on a later page. The same condition appears to prevail generally in regard to the diseases of insects caused by fungi (Fig. 25), bacteria and other microörganisms, but this matter has been carefully investigated in only a few cases and it would seem inadvisable to make very definite statements at the present time.

Predatory insects also play an important part in reducing the abundance of phytophagous insects. In habits they are directly comparable to the beasts of prey among the higher animals, which destroy the weaker and more timid mammals. They do not show the same close correlation to their prey exhibited by insect parasites and cannot usually be depended

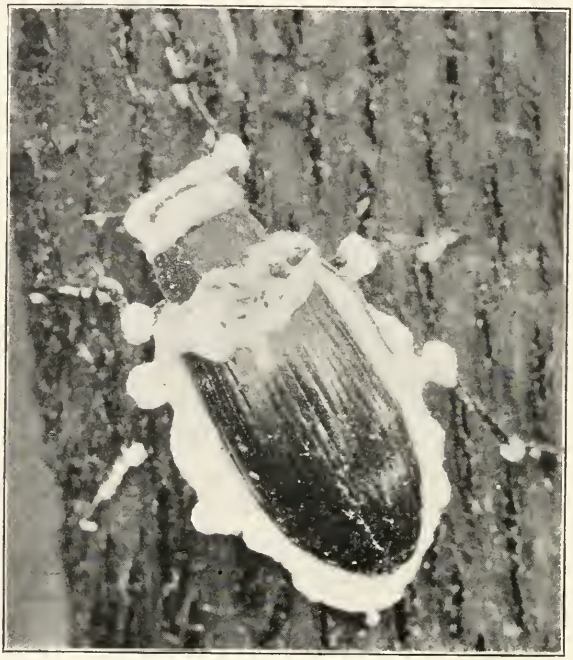

FIG. 25. A common beetle (*Helops micans*) killed by a parasitic fungus.

upon to restrict their depredations to any particular insect pest. Quite frequently, however, they are a great aid in combination with parasites and several exotic ones introduced into the United States have aided in the control of the gipsy moth, scale insects, etc.

Another factor which must not be overlooked, relates to the provenience of our agricultural crop plants. These are the result of selection during the course of many centuries, and have been gathered together from the most diverse parts of the world. Thus most of them are grown to a very great

extent outside of their natural habitat and consequently find themselves frequently and to varying extents, free from at least some of their original insect pests. With the gradual growth of world commerce and the great increase in the ease and rapidity of transportation, insects are more easily carried over natural barriers and the aggregation of agricultural pests is continually becoming more homogeneous.

As was mentioned before, cultivated plants are often attacked by insects which have previously fed on related plants and such occurrences, although uncommon, are by no means rare. Many of our most important food plants belong to a very few of the natural families of plants and it is noticeable also that these plant groups are usually very widely distributed ones with many representatives. Thus the grasses or Gramineæ furnish us with wheat, Indian corn, oats, rye, barley and sugar cane; the Leguminosæ with beans, soy beans, chick peas, peas and cowpeas; the Solanaceæ with the potato, tomato, sweet pepper and egg plant, the Umbelliferæ with carrots, parsley, celery and parsnips; the Cucurbitaceæ with the pumpkin, squash, vegetable marrow, cucumber and melons; the Cruciferæ with cabbage, cauliflower, Brussels sprouts, kohl-rabi, mustard, turnips and radishes; the Compositæ with salsify, lettuce, and the Jerusalem artichoke; the Polygonaceæ with buckwheat and rhubarb; the Liliaceæ with asparagus, onions, leeks, garlic, etc.

There are, of course, very numerous exceptions to this as is the case in food plants like the beet, sweet potato, etc., but these only modify the general principle that the utilization of numerous related plants is the common practice. It is noticeable also that a good many of these plants are of tropical or semitropical origin, and that they are commonly cultivated in climates far more rigorous than those in which they have originated. This is true of a large variety of well-known food plants like corn, potatoes, tomatoes, pumpkins, etc.

As might naturally be expected from the foregoing, we actually find that some of our pests of wheat are species

occurring on, and probably original enemies of native American grasses, several of which are very closely related to the cultivated wheat plant. A still more interesting case is that of the Colorado potato beetle (Fig. 26), a well-known and very destructive enemy of the potato (*Solanum tuberosum*). We have good evidence that this is a neotropical insect of Mexican or Central American origin which extended its range within historic times into the middle west as far as

Fig. 26. The Colorado potato beetle (*Leptinotarsa decemlineata*), originally a wanderer from Mexico, now firmly established in practically every potato patch. The larva is shown at the left.

Colorado, following the probable northward migration of its original food plant, *Solanum rostratum*, which is a common roadside weed. In the late sixties of the past century it was first noticed feeding on the foliage of cultivated potatoes and within twenty-five years had encompassed the entire United States east of the Rockies, breeding upon potato plants everywhere, and even invading Europe where its incipient colonies were wiped out.

This same group of plants, the Solanums, also illustrates nicely the vagaries of numerous insects in relation to food plants. Thus we find that the Colorado potato beetle now feeds upon *Solanum rostratum* far less commonly than upon potatoes and that it does not occur at all on the tomato or

egg plant, both of which are species of the same genus, although it occasionally affects tobacco. On the other hand,

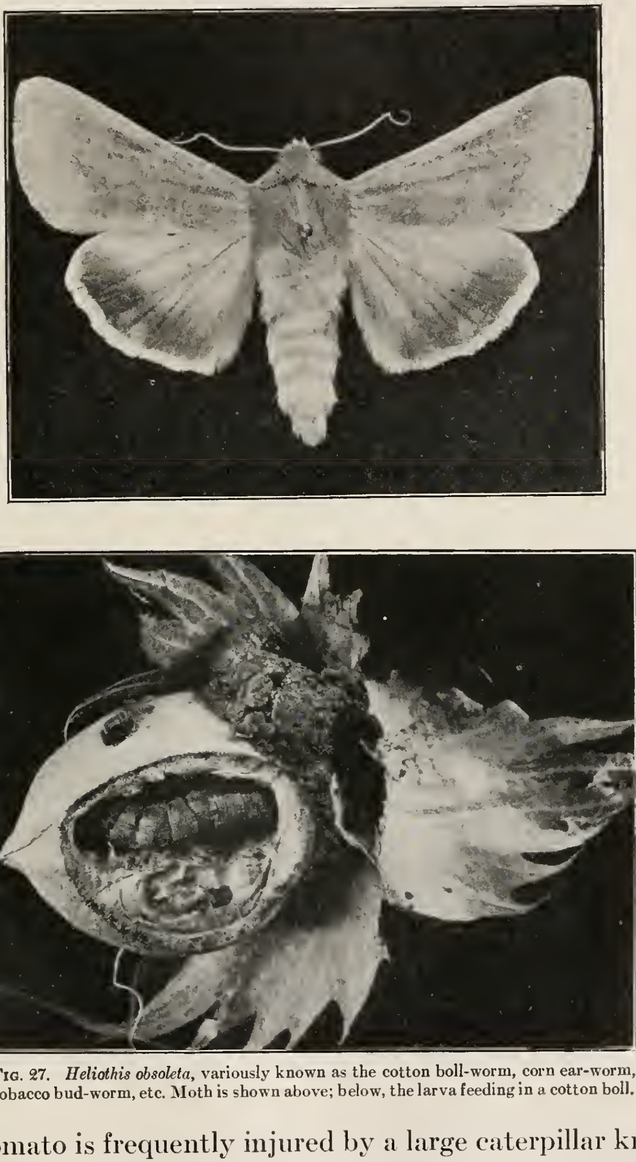

FIG. 27. *Heliothis obsoleta*, variously known as the cotton boll-worm, corn ear-worm, tobacco bud-worm, etc. Moth is shown above; below, the larva feeding in a cotton boll.

the tomato is frequently injured by a large caterpillar known as the tomato fruit-worm (*Heliothis obsoleta*) (Fig. 27) which

does not occur on the egg plant or potato, although it is the common enemy of tobacco known as the bud-worm, and is moreover a very important enemy of both corn and cotton, two totally unrelated plants. On these latter it has been called the corn ear-worm and the cotton boll-worm, but it is identical and feeds on these several plants without much apparent choice.

Insects of this type point out clearly the fallacy of any statement that related plants always have the same or related insect pests. That they quite generally have the same enemies or nearly related ones with similar life history and habits is, however, ordinarily quite true.

How can this damage be abated or lessened is the natural inquiry from the non-academic mind. We have seen that a return to natural conditions would speedily reduce insect injury and bring into play the forces of nature which would maintain a more or less stable condition. Such a return would not take place, however, if human influence were simply removed; it is true that a stable condition would result, but it would be very different from that which existed in the original flora and fauna. Indeed human ingenuity could not again make things as they were, even if it were desired to do so at the cost of discarding all agricultural progress. It is, however, possible by an additional disturbance to approach in some respects to a natural biological association without disturbing agriculture in the least degree.

This partial return to the native environment can be achieved to some extent by the introduction of parasitic insects and other organisms, and this biological method of combating imported insect pests has proved itself of value in many cases. Up to the present time the importation, colonization and distribution of such enemies has been accomplished in this country with the parasites of the gipsy moth and to a less degree with those of certain other insect pests. The method gives great future promise, but there are many technical difficulties to be overcome. Its great advantage lies in the fact that it insures permanent relief once it has

been started, and that its limitations are in a broad way determined primarily by the insect species against which it is directed. Aside from the repeated application of poisons and other insect-destroying materials, it is the only feasible means except those which entail changes in agricultural procedure.

Of the latter methods, there are several which can be employed without seriously disturbing agriculture, and at least one of them is, in fact, only a slight modification of the principle of the rotation of crops which had its origin not in relation to insects, but as a practice to delay or prevent the loss of soil fertility.

We have already seen how the continued presence of the same crop plant in the same place from year to year serves to augment insect depredations. Since many different crops have insect enemies in common, it follows that when such crops follow one another on the same area, the opportunities for insect multiplication are not conspicuously less than if there were no rotation. Similarly the planting of newly plowed grass-land to corn, wheat or other grasses courts disaster in the same way. Rotation practised with insect injury in mind, however, where the crop plants are without important enemies in common, serves to reduce insect injury to at least some extent, dependent mainly upon the ability of the insects concerned to migrate, and it need in no way impair the other advantages derived from the process. Agricultural entomology has now reached such a condition that reliable advice with reference to many insects can be given in this matter.

A concrete example of the utilization of this method in the control of certain insects that are difficult to combat otherwise has recently been demonstrated. In this case the insects are the large grubs of May-beetles which feed on the roots of many plants. They are particularly injurious to corn in the northern middle states, but do not injure clover nor do they deposit their eggs in soil that is covered by a stand of clover. In this region corn is commonly planted in rotation with timothy, oats or barley, but if clover is grown the year before

a field is to be planted to corn, few grubs will be present in the cornfield. As the beetles require two years for their life cycle, appearing most abundantly in alternate years, the crop rotation can be planned in relation to the insects.

The growing of substitute crops is practically this method applied in a somewhat different way, and has the further advantage that the original crop is not removed to a distance, but is more or less completely eliminated. This is a rather fundamental agricultural change and it must be taken for granted also that a substitute is something less desirable. As some of us have become rather enthusiastic over substitute foods during the past few years, it may be of interest to point out that two potato substitutes, the dasheen in the South and edible sunflower root or "Jerusalem artichoke" in the North are plants which appear to be, for the present at least, not severely affected by insects, and for this reason at least are worthy of encouragement.

Aside from the factors already referred to as regulating the abundance and destructiveness of agricultural insects, various poisons are in very general use for the control of such pests. Under present conditions these are the most direct, and probably the most efficient means, that can be employed for the protection of many crops, although with others there are apparently insuperable difficulties to the satisfactory use of such insecticides.

At the time the Colorado potato beetle began its invasion of the Eastern United States agriculturists were in despair, as it appeared that the cultivation of this important crop would have to be abandoned almost entirely over large sections of our country. However, as a result of the discovery that Paris Green dusted or sprayed upon the foliage would destroy the beetle grubs without injuring the plants, the potato crop was harvested in spite of the beetle, and spraying for potato bugs has become a commonplace occupation for all who attempt the culture of potatoes. The substitute of other less soluble arsenical compounds such as arsenate of lead has rendered spraying a more effective and safer procedure, and

careful studies of the life history and habits of specific insects have greatly extended the field of usefulness of the arsenical insecticides. This is well illustrated by studies made on the codling moth by Melander. This insect is a very important enemy of the apple, within the fruit of which its developmental stages are passed. It is usually controlled by spray-

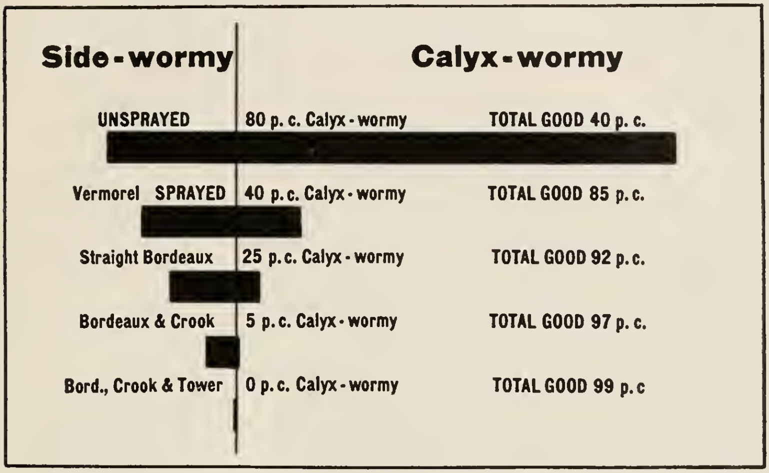

Fig. 28. Chart illustrating the effects of spraying with lead arsenate by different methods for the control of the codling moth (*Carpocapsa pomonella*), a widespread and serious insect enemy of the apple. In this case unsprayed trees yielded only 40 per cent of good fruit, while of the wormy fruit, 80 per cent became wormy from larvæ entering the fruit at the calyx cup; when sprayed with a Vermorel nozzle giving a mist spray, 85 per cent of the fruit was good, while of the wormy fruit 40 per cent became wormy from larvæ entering at the calyx cup; when sprayed with a Bordeaux nozzle giving a forcible, penetrating spray, 92 per cent of the fruit was good, while of the wormy fruit 25 per cent became wormy from larvæ entering at the calyx cup; when sprayed with a Bordeaux nozzle set at the proper angle by means of a crook, 97 per cent of the fruit was good, while of the wormy fruit 5 per cent became wormy from larvæ entering at the calyx cup; finally, when the latter spraying was done from a movable tower, 99 per cent of good fruit was obtained and no apples became wormy from larvæ entering at the calyx cup. (After Melander.)

ing the young fruit with an arsenical, but the advantage gained varies within very wide limits depending upon the exact time at which the spray is applied, the method of application, and the type of nozzle used. Slight modifications in the form of calyx cup of the young apple, due apparently to different climatic conditions, have in turn a profound influence upon the efficacy of the spray, and in some regions, several sprayings must be substituted for the single one found to be effective at other places (Fig. 28).

Thus, in spite of their simplicity of action, arsenical sprays can be prescribed with confidence only after a careful and painstaking diagnosis has been made.

The arsenical insecticides are usually referred to as stomach poisons as their toxic action is accomplished through the medium of the alimentary tract. As we have seen, they are readily ingested by chewing insects when applied to the plants upon which such insects are feeding. Many of our most destructive insects do not feed by chewing however, but subsist upon juices which they extract from their food plant by means of a piercing, sucking beak which is thrust into the tissues of the plant. Such haustellate insects manifestly will not take into the mouth any arsenical poison present upon the surface of the plant, and no successful means have been devised for introducing poisonous materials into the sap with which they might be taken into the body of the insect.

For the destruction of such insects, other materials, known as contact insecticides are in general use. These consist of various substances, such as nicotine, certain sulphides and oil emulsions, etc., which kill through contact, by actual poisoning, suffocation or otherwise.

These are often used in combination with the arsenicals and with a fungicide such as the copper compound known as Bordeaux mixture. Thus when several insects of different types and fungous diseases are to be dealt with upon the same plants, specific combinations may be prescribed. Some of the methods of treatment available for application to various fruits are shown in the accompanying diagram (Fig. 29).

After foods are harvested they are commonly stored for considerable periods before they are finally utilized, especially in the case of staple crops such as cereals, beans, etc. During this time they are by no means free from insect injury, in fact, their deterioration is undoubtedly hastened more by insect activity than by any other agency. The insects concerned are a most cosmopolitan lot, gathered from all quarters of the globe, for their world-wide dissemination

has been most readily accomplished in the extensive shipments of such products. The Orient is represented by several Chinese bean-weevils which affect the stored seeds of leguminous plants; southern Europe by the Mediterranean flour

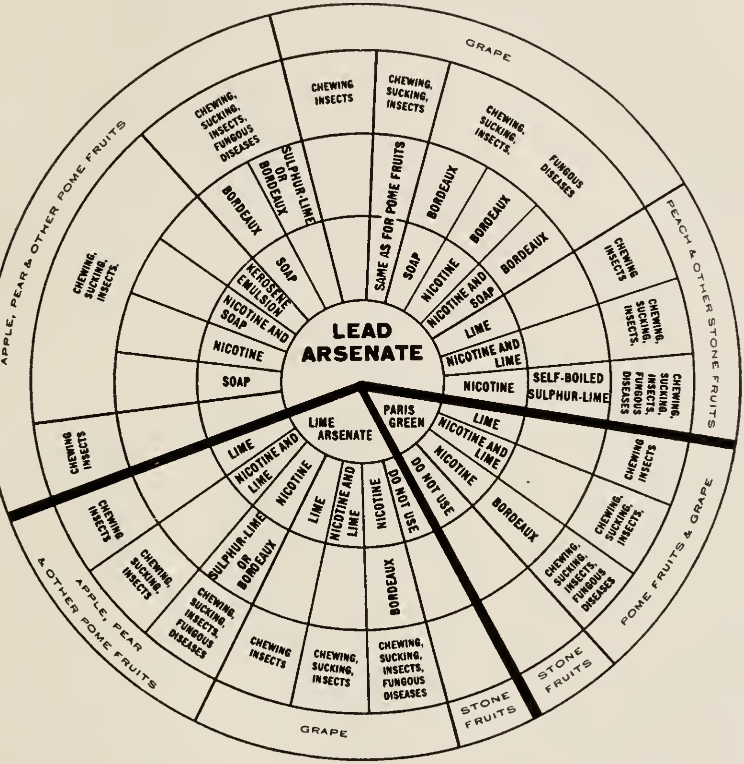

Fig. 29. Diagram illustrating the various combinations in which several arsenical insecticides may be combined with contact insecticides and fungicides for the protection of certain orchard fruits from insects and fungous diseases. In the figure, the sections between the heavy black lines represent the combinations suitable with three different arsenicals, while the smaller sectors represent suitable treatment for several types of injury to the particular plants that are indicated about the periphery of the diagram. (Slightly modified from Quaintance.)

moth, Mexico by the Mexican grain beetle, etc., while the majority of the more common ones are so widely scattered that it is almost impossible to ascertain their original home.

Owing to the non-living character of the material in which these insects live, it is possible easily to control them by means of simple physical or chemical means such as heating

to a temperature that will destroy insect life, or fumigation by some insecticide such as carbon bisulphide, carbon tetrachloride or hydrocyanic acid gas, after which they may be marketed in sealed containers. In spite of the ease with which these insects can be controlled, they entail an immense economic loss which is probably in the neighborhood of $20,000,000 annually in the United States. Their origin as enemies of stored products which are maintained under purely unnatural conditions, may at first sight seem a trifle obscure, but they all undoubtedly represent species originally enjoying very limited opportunities for multiplication, and subject to great vicissitudes. Like agricultural pests they now flourish with the barriers removed.

CHAPTER III

FOREST INSECTS

The necessity for the conservation of forests and the rational utilization of their products has long been recognized by all who have given attention to such matters. Changes in private and public policy have come slowly, however, and until recently but little attempt has been made to manage forests with regard to both their present and future value. As a consequence, forestry has lagged far behind agriculture and although "forest conservation" has now become a byword with the American public, its history in our own country is very brief. Despite the great value and vast importance of forest products, it is easy to find a reason for the more rapid application of scientific ideas to agriculture, for there the results of improved methods manifest themselves within a single season. On the other hand, timber trees are of slow growth, and unlike agricultural crops, they have existed in enormous quantities ready for man's use without any effort on his part to further their growth. So long as primeval forests were available in sufficient amount and in convenient locations, little care was taken to provide for a future supply of lumber. In fact it was tacitly assumed that nature would provide a continuous supply of trees, and she was left to her own devices to replace what human agency had removed.

Under the conditions now prevailing, she has consistently failed to replace forests that have been removed, mainly on account of fire and other disturbing elements resulting from human activity. Thus to one section of the world after another, has come the realization that forestry must be put on a permanent basis if forest products like agricultural crops, continue to be necessary for human existence. There appears to be no promise of a future which will lessen its demands

upon the forests and there is every probability that they will be called upon in rapidly increasing measure.

The problems entailed in maintaining forests in a productive state and those to be dealt with in rehabilitating depleted ones, or in fostering the development of new ones, are numerous and intricate, but manifestly they have much in common with those encountered by the agriculturist. One of the most striking differences is the element of time, due to the slowness with which the lumber crop matures in comparison with the rapid development of the common annual agricultural crops. This element of time at once exerts a profound influence on the commercial aspect of the matter, since the returns on the money invested in forests and that spent in their maintenance are so delayed that they dwindle in amount when compared with those which may be obtained from investments of other kinds. Added to this, is a psychological aspect due to the deep-seated human aversion for rewards in the too distant future. These matters could be dwelt upon at great length, but they are far from the present discussion, except that they explain in great measure the past and present relations between the human race and the forests. One point which must be borne in mind, is that the element of time bears also a very important biological relation to the welfare of forests. This is least noticeable in many primeval forests of mixed character, but becomes increasingly significant in those of pure growth, and those which are reproducing themselves after depletion through extensive cutting, while it is of prime importance under the conditions prevailing where extensive reforestation is undertaken.

We have pointed out, in connection with the insect enemies of agricultural crops, the general relationship which exists between these plants and insects. In the case of forest insects, it will soon be seen how greatly the long developmental period of trees affects the character of the depredations of insects that live at their expense. Another difference which influences damage by insects, depends upon the devel-

opment of woody tissue, which is practically absent in all of the agricultural crop plants, and which serves as food for quite a considerable variety of insects. On the other hand, the large fleshy roots so characteristic of many food plants are not developed in trees, which are consequently not injured by insects of the type that are so destructive to vegetables like the carrot, radish, etc. With the horticultural trees like the apple and peach, forest trees have more types of insect enemies in common, but with the exception of the nut trees, palms and a few others the fruit of forest trees is of little consequence so long as sufficient seed is produced to allow for reproduction. In exceptional cases, certain insects actually do prevent the development of seeds to such a degree as to menace seriously the reproduction of certain species of coniferous trees, but ordinarily their influence upon seed production is not of any great importance.

Aside from the fundamental differences in material composition between the individual tree and herbaceous agricultural plant, and not to consider for the moment, the slow development of the tree, we find another very striking difference in the environment encountered by the insects which feed upon the two types of plants.

In the previous chapter on agricultural insects, attention has been called to the way in which associations of very diverse plants have been replaced by large masses of crop plants belonging to single species. This change has upset entirely the balance which exists under natural conditions between the plants and their insect enemies. Many forests are comparable to the miscellaneous association of plants which have given place to cultivated fields, and in fact, much of the present agricultural land was once covered by forests. On the other hand many forests, e.g., those consisting of coniferous trees, are frequently composed of single species growing to the practical exclusion of all others over very extensive areas. When such is the case, the situation is very similar to that presented by agricultural plants. It is, however, fundamentally different in at least one respect: these trees are

growing under natural conditions, and with their slow growth, could never have reached their present age if they were regularly subject to damage comparable to that inflicted upon agricultural plants growing continuously in pure stand. These coniferous forests present peculiar conditions in relation to insect damage which are of great importance at the present time, and they afford interesting material for speculation as to the damage which may be caused by insects in the future, to any pure forests of other kinds of trees that may be planted for specific purposes.

A characteristic of the insect damage to coniferous forests is the great fluctuation which it exhibits both in extent and severity from year to year. The appearance in great abundance of many of the insect enemies of conifers often shows a striking similarity to the epidemics of certain human diseases, although the reason for their later disappearance is undoubtedly due to very different causes. One common insect of Europe is of especial interest since it is a close relative of the gipsy moth, already introduced into the United States. This is the nun moth (Fig. 30), feeding in the larval stages upon the foliage of various conifers. When the caterpillars are abundant, they may completely defoliate trees over wide areas and cause them to die in large numbers, as coniferous trees very frequently fail to survive complete defoliation. The more important and extensive "epidemics" of the nun moth experienced in recent times occurred in 1795, 1839 and 1890, or approximately fifty years apart. Since this is about the period required for the individual trees to attain a mature size, the appearance of the insects shows a very interesting parallel to the more or less regular appearance from year to year of many insects destructive to annual agricultural plants. In the case of trees of this sort, it is evident that a more frequent occurrence of such outbreaks would seriously menace the continued existence of the host-tree species. The earlier outbreak cited above was suddenly terminated during the third summer as the result of the appearance of a fatal infectious disease of the caterpillars, and such disease, as well

as parasitic insects, in combination with a scarcity of food, are undoubtedly responsible for the curbing of many invasions of this kind.

In both Europe and North America the larch tree is affected by the leaf-feeding, caterpillar-like larva of the larch sawfly, an insect common to both continents. Like many

Fig. 30. The nun moth (*Psilura monacha*), an important enemy of coniferous trees in Europe. This insect was once found in Brooklyn, N. Y., but was stamped out before it had opportunity to spread.

other forest insects, this species has in a number of instances, appeared suddenly in great abundance in localities where it had previously been hardly noticed for many years. Since the middle of the last century, there have been about half a dozen outbreaks of this kind, culminating in a very widespread one in 1903–1907 which involved a considerable part of the area in the eastern part of America where the larch is native, and caused the death of a large proportion of the mature larches in this region.

During the past decade certain parts of eastern Canada and a considerable portion of the State of Maine have suffered from an invasion of the spruce bud-worm (*Tortrix fumiferana*), an insect which defoliates the balsam fir and spruce. This insect has moved like the incoming tide and extended its destructive range from year to year. The spruce woods of northern Maine that furnish much of the pulpwood from which some of our better class papers are produced have suffered severely for several years. During this period certain areas have in succession lost a goodly part of their tree population of spruce and balsam fir, after which the insects have suddenly disappeared. If we can judge by the past history of this species, it will not again reappear in destructive abundance for many years. As a result of its ravages, however, there is grave danger that these forests may be replaced by more rapidly growing and less valuable hardwood trees which would not under natural conditions again give way to spruce and fir for perhaps two or three hundred years. In the history of the world this is a mere incident, but it is a very severe blow to one of our important present-day industries.

In the northwestern states and western Canada there is a small, pale yellowish-white butterfly, quite similar to the common European cabbage butterfly now so abundant in the United States. It feeds during its larval stages upon the foliage of several kinds of western conifers, and over the short period during which it has been observed, has several times suddenly appeared in incredible numbers in rather definitely circumscribed areas. At such times, extensive portions of the forests are defoliated, and the trees succumb as a result of the injury.

This insect and others that produce the general defoliation of coniferous trees may not always cause the immediate death of the trees, but in cases where the weakened trees might otherwise recover, they open the way for depredations on the part of another group of destructive insects known as the bark-beetles. The latter are small, brownish or blackish, hard-bodied insects, represented by numerous species that

live at the expense of trees of almost every description. Some of the larger ones, belonging to the genus Dendroctonus (Fig. 31), attack perfectly robust, healthy trees, but the majority live in weakened, moribund, or dead trees. Those of the first type commonly appear in the form of invasions or epidemics, of which many have been noticed in our own country, from time to time. The others find great opportunities

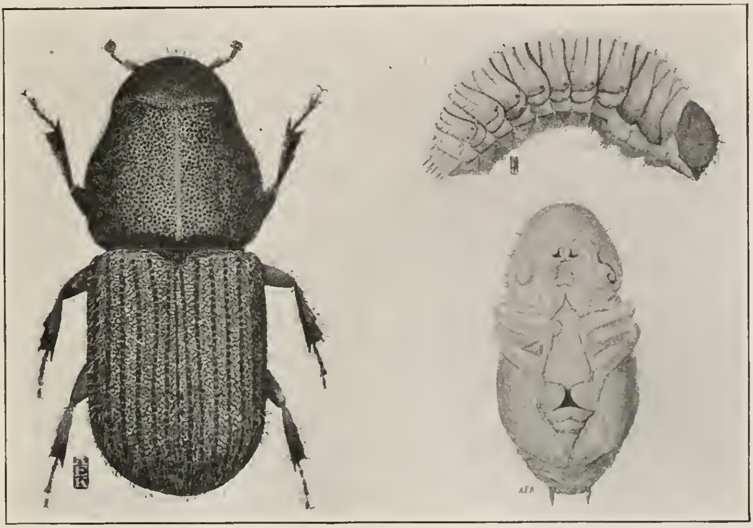

FIG. 31. A bark-beetle (*Dendroctonus monticolæ*); adult beetle, larva and pupa. (After Swaine.)

for multiplication following sporadic outbreaks of other insects like those mentioned above, and may complete the ruin of considerable areas of forests that might eventually have recovered from the effects of partial, or even complete defoliation.

Fortunately the bark-beetles that kill healthy trees are few in number, but they are rather widespread in our own country, and our coniferous forests have suffered greatly from them in numerous instances. Destruction in these cases also, has usually been due to sudden outbreaks of limited duration. Thus, at several times during the last century, spruces in the northeastern states have been killed over rather definite areas

by the spruce bark-beetle (*Dendroctonus piceaperda*). With this, as with other bark-beetles, the parent beetles excavate galleries in the inner bark or cambium, along which they deposit their eggs. When these eggs hatch, the larvæ burrow off to the sides where they feed upon the cambium layer until they attain full growth, after which they bore their way through the outer bark, and leave the tree. Extensive injury to the cambium interferes with the metabolism of the tree and kills it after the manner of the girdler's axe (Fig. 32).

More spectacular than the work of the spruce bark-beetle, has been that of the Black Hills beetle (*Dendroctonus ponderosæ*. Following its sudden appearance in large numbers in the Black Hills National Forest of South Dakota, during the season of 1897, its ravages assumed the proportions of an epidemic there, and Hopkins has estimated that trees containing nearly a billion feet of timber were killed before the epidemic subsided several years later.

As mentioned on a previous page, mixed forests present a somewhat different problem to the entomologist from that just discussed in connection with the unmixed, or pure growths of coniferous forests. Our mixed forests are composed mainly of deciduous, or broad-leaved trees, and these ordinarily contain a well-mixed assortment of tree-species belonging to at least several of the natural families of plants, combined with much shrubby and herbaceous growth. They at once exhibit a great diversity of plants, and support a correspondingly large and varied insect fauna. A considerable proportion of these insects are species dependent upon the plants other than trees; some live upon the rotting wood or bark of fallen trees, others upon fungi, many are predatory or parasitic upon the foregoing, till only a small number remaining, are actually destructive forest pests. These in turn, are each almost entirely restricted to one or several related trees as food plants, so that the inter-relationship of trees and insects becomes a very complicated one. It would seem that such an environment should tend to equalize the damage done by insects to specific kinds of trees, from year to year,

and to inhibit the development of extensive outbreaks. Such a conclusion appears to be borne out by experience, except in

Fig. 32. Work of the Black Hills bark-beetle (*Dendroctonus ponderosæ*) on the inner surface of the living bark. The vertical galleries are excavated by the parent beetles and the smaller lateral ones are the food burrows of the larvæ. The entrance holes (a) are at the lower end of the primary gallery, which is ventilated by other holes, indicated as white spots. (Slightly modified from Hopkins.)

a few cases, and there the explanation must be sought for along other lines.

It might appear from such a brief comparison of insect damage to pure coniferous forests (i.e., those which practi-

cally inhibit the development of undergrowth on the forest floor) with mixed forests of deciduous trees, that we may have overlooked some fundamental principle regulating insect damage to trees of the two types. That such is not the case is shown by the less noticeable, and more restricted outbreaks of certain species that occur in deciduous forests where one species of tree may greatly predominate, or in cases of insects that readily attack a considerably extensive series of trees. That the excessive importance of forest insects in our own country may in part be due also to the great amount of waste, uncared-for land suggests another factor which may perhaps modify these conclusions.

The striped maple caterpillar (*Anisota rubicunda*) is an example of the first type mentioned above. This is a defoliating species, of rather general distribution in the cooler portions of eastern North America. It is naturally always more abundant where maples are numerous, but occasionally appears in localized outbreaks of quite definite duration. An example of the other type is the European gipsy moth (*Porthetria dispar*, Fig. 33), now prevalent in a part of New England where it became established as a result of accidental introduction, through the agency of man.

The gipsy moth lives as a caterpillar on the foliage of a large number of deciduous trees, and will, when pressed for food, devour with evident relish many shrubs. Even the foliage of pines and other conifers will serve as food for the caterpillars after they have become partly grown. Although certain trees such as the oaks are its favorite food it is a truly polyphagous insect and a forest of deciduous trees contains few species which it will not readily attack. It finds commonly, therefore, conditions very similar to those encountered by the enemies of coniferous trees. Consequently, we find that its history in Europe, as far back as it has been recorded with accuracy, includes a series of sudden outbreaks. Thus in Europe in 1731, 1761, 1794, 1837, 1871, and 1909, certain localities were visited by hordes of these caterpillars which defoliated everything in the vicinity. It is very re-

markable to note the great regularity with which these outbreaks have occurred (respectively 30, 33, 43, 34 and 38 years apart), particularly when it is remembered that they have in no way been coincident geographically. It must be remembered, of course, that at many intermediate dates there have been subsidiary outbreaks of lesser severity, and more restricted range, but the periodicity of this insect, and that of

FIG. 33. The gipsy moth (*Porthetria dispar*). The female moth is shown above and at the left. The dark colored specimen is the male.

the nun moth mentioned on a previous page, are undoubtedly manifestations of some principle which influences the destructiveness of many forest insects.

In connection with agricultural insects we have already called attention to the importance of entomophagous parasites, and the regulatory effect exercised by these is fully as great in the case of forest insects. In fact some of our most accurate knowledge of the economic value of parasitic insects has been gained through a study of the parasites of the gipsy moth, which was made on an elaborate scale by the Federal Bureau of Entomology in its well-directed efforts toward preventing the spread, and curbing the destructive activities

of the gipsy moth in New England. Since this insect bids fair to become one of the worst forest insects over a considerable portion of North America, it may be worth while to review its status, in regard to natural control by parasites, in both Europe and America. It was first introduced into the United States about 1868, in a little town near Boston where it did not become sufficiently abundant to attract attention for nearly twenty years. Since then it has spread very slowly, but persistently, in spite of the various repressive measures undertaken to prevent its multiplication and dissemination (Fig. 34). At the present time it is the most abundant caterpillar feeding upon trees over a large part of its range, and has caused unbelievable havoc in the woodlands of eastern Massachusetts and contiguous territory.

The slow rate of spread of the gipsy moth is in striking contrast to that of the European cabbage butterfly which has been cited on another page, and aside from the vigorous repressive measures undertaken to delay its dispersion may perhaps be due to the inability of the adult female moths to fly. On this account, aside from accidental transportation, the species must depend upon the larva for migration, and, when newly hatched from the egg, these are commonly blown to considerable distances by the wind. Nevertheless, a closely related European moth, the brown-tail moth (*Euproctis chrysorrhœa*) first detected in 1897, at almost the same place as the gipsy moth, has in twenty years encompassed but little more territory. It is now distributed over a narrow coastal strip scarcely over 100 miles in width from Cape Cod northward through Maine in Canada. The slow movement of these pests is gratifying from an economic standpoint, but is of only temporary significance, as both are undoubtedly destined to cross the entire continent, and to assume nation-wide importance. The cause of the slow spread of the brown-tail moth is not easily to be pointed out, as this species flies readily and finds its favorite food plants widely distributed. Several factors are undoubtedly concerned, relating to meteorological conditions, as well as the nomadic instincts of the moths themselves.

In Europe the gipsy moth has a number of insect parasites and these serve to reduce its numbers greatly below those

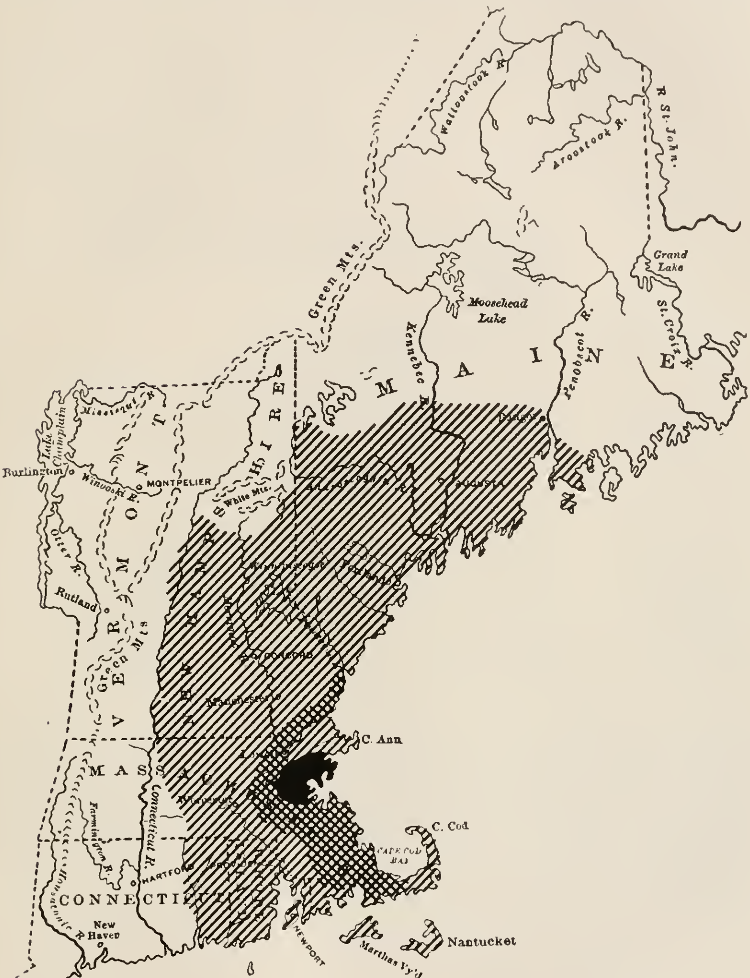

Fig. 34. Map of the New England states showing the spread of the gipsy moth (*Porthetria dispar*). In 1900, twenty years after its introduction near Boston, it had spread over the area marked in black; the cross-hatched lines indicate its distribution in 1905, and the slanting lines its range in 1918.

present in the infested American districts, although as we have already seen, severe outbreaks in Europe are by no means unknown. In Japan, the species is still less destruc-

tive, presumably on account of more efficient control by parasites. Since parasites capable of attacking the moth were practically absent in the American fauna, an extensive attempt has been made to colonize the Eurasian parasites on this continent. This work has been well under way for about ten years, and after numerous technical difficulties, a series

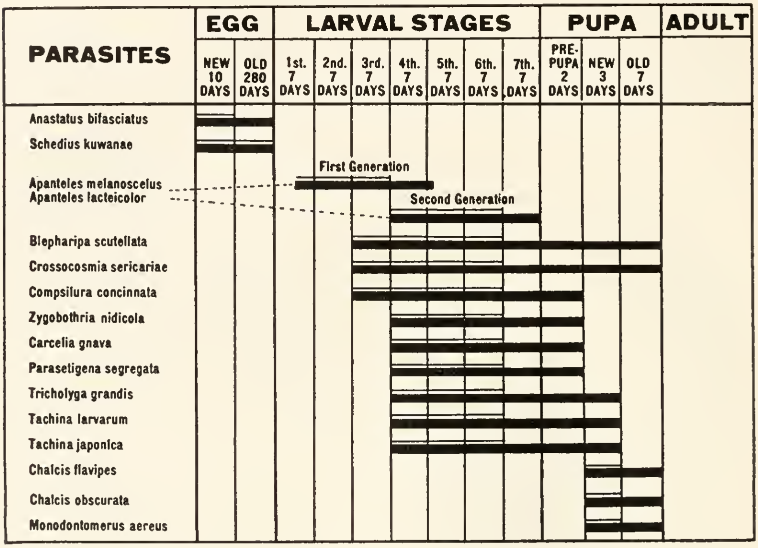

Fig. 35. Chart illustrating the way in which parasitic insects aid in the control of an insect pest. The sixteen species mentioned are some of the most important parasites of the gipsy moth in Europe and Japan where this insect is native. Of the large series introduced into the United States, they are the most promising enemies of the gipsy moth as they appear to have become most readily acclimated and to have multiplied most satisfactorily. Two species attack the moth eggs, eleven attack the caterpillars and three the chrysalids. The light lines indicate the stages of the host during which the parasites attack it and deposit their eggs, while the heavy lines indicate the ages of the host during which the parasitic insects may live within its body. A series or sequence of parasites acts as a much more efficient hindrance to the multiplication of an insect pest than any single parasite, no matter how abundant. (Modified from Howard.)

of the parasites were successfully imported and liberated (Fig. 35). Some of these bid fair to become of great value, and they have a great advantage over arsenical sprays and other methods of control, in that they maintain themselves when once established, and do not require repeated human effort with a lavish expenditure of money from year to year.

Efforts are also being made to foster certain diseases of the gipsy moth which cause a high mortality among the

caterpillars. One disease is now very prevalent, and attempts are being made with good prospect of success to introduce another one which occurs in Japan. Also a large predatory European beetle (*Calosoma sycophanta*) (Fig. 36) which feeds upon the caterpillars has been liberated in America, and has multiplied with astonishing rapidity.

This method of control is particularly adaptable to forest insects, since the principle of annual rotation as applied to

Fig. 36. *Calosoma sycophanta*, a European beetle introduced into the United States to combat the gipsy moth. Both the larval and adult beetles feed upon the caterpillars of the moth.

agricultural crops is impossible in the case of trees, and although long term rotation is possible, it does not bear the same relation to insect abundance. Spraying also is unprofitable, and not at all practicable except under exceptional circumstances. It appears, therefore, that control of forest insects cannot be undertaken along as many lines as that of agricultural insects, and from this point of view at least, forest insects present much the more difficult problem.

The relation of parasites to the abundance of the gipsy moth in America cannot, of course, be regarded as entirely similar to that existing in Europe where the moth is native, and an inquiry into the parasitic control of this moth in its native home, or of any of our native insects will reveal much

more accurately the nature of the regulatory effect of parasites in the case of most of our forest insects. One common native insect enemy of deciduous trees, closely related to the gipsy moth, is the white marked tussock moth (*Hemerocampa leucostigma*). This species is especially destructive to shade trees in cities. The caterpillars, which are familiar to nearly everyone, are beautiful objects, adorned with pencils of black and scarlet hairs, and with dense tufts of buff-colored hairs on the back. They are periodically abundant in most of our eastern cities, usually increasing in numbers for several years, and then rather suddenly almost disappearing, gradually to regain their previous abundance.

Some years ago Howard showed that the preparatory stages of the tussock moth are subject to attack by at least twenty-one primary parasites, belonging to several different families of insects. These in turn fall prey to fourteen hyperparasites which attack the primary ones and thus tend to reduce the numbers of the latter, although they do not prevent the destruction of the parasitized caterpillars in any case. There are two or three broods of the tussock moth each season and, as has been noticed in the case of other insects having more than one brood each year, the first is less heavily parasitized than the second, or later ones. This is probably due to a greater mortality during hibernation among the parasites than with the host, so that the host species usually shows a lesser degree of parasitism early in the season, but due to a greater prolificacy and rapidity of multiplication, the parasites gain the upper hand later in the season, only to lose most of their advantage during the hibernating months. However, when the host has been especially abundant one year, and thus permitted an unusual increase among its parasites, it may be very highly parasitized early the next season. Such a condition was noticed with the tussock moth by Howard in Washington, in 1895 and 1896. During the season of 1895 this pest had shown an enormous increase, and threatened the destruction of shade trees throughout the city. The third or autumn brood was

very heavily parasitized, and on examining the pupæ of the first brood during 1896, it was found that from 624 cocoons collected only 12 moths emerged, while from those remaining (excluding a few which had died of disease) no less than 916 specimens of parasitic insects emerged, indicating a mortality of over 98 per cent. This explains very satisfactorily the great fluctuation in numbers noticed with this species, as also with many other pests which gradually become more and more abundant from season to season for a number of years, and then suddenly suffer a set-back, are greatly decimated, and become relatively unimportant for a number of years, until they can regain their lost ground. When again very abundant, their parasites enjoy unusual opportunities for multiplication, and there is another abrupt decrease in the numbers of the host species.

The condition just described is similar in a way to the outbreaks of other forest insects discussed earlier in the present chapter, but although the depredations terminate suddenly in both cases, their appearance is gradual in one instance, and quite without warning in the other. Possibly entomologists have only failed to read the signs aright, but it seems more likely that most extensive and unexpected invasions are due to other causes.

One interesting case of an insect enemy of deciduous trees, which closely parallels the condition seen with agricultural insects, is that of the locust-borer (*Cyllene robiniæ*), an enemy of the yellow locust (*Robinia pseudacacia*). The larvæ of the locust-borer feed within the sapwood of living trees where they tunnel in the trunk and branches. This tree is native over a very restricted range along the Appalachian Mountains from Pennsylvania to northern Georgia, but has been planted over wide areas throughout the eastern states, on account of its rapid growth and valuable timber. The locust-borer has spread with its host tree, and the thickly planted groves of locusts have offered such opportunities for the multiplication of the insect that the propagation of these trees has been abandoned in many localities where they might otherwise have been grown very profitably.

The age of individual trees may exercise a considerable influence upon the amount of damage caused by insects. It may be stated, with few reservations, that where old or well-matured trees occur among very healthy and vigorous young specimens, that the former are almost always more liable to attack. Thus from an entomological standpoint, the felling and removal of the older and more mature trees in a forest that contains individuals of mixed ages, is a very wise and satisfactory practice. Even though the younger trees are less readily killed by insects, their growth may be temporarily checked, and a part of the increment to the forest by rapid growth may be lost. However, if the fully matured trees had borne the brunt of the attack, they would quite possibly have succumbed altogether, and have served, in addition, as breeding places for a much larger brood of insects to attack the remaining trees the next season. The relation which this bears to proper forest management is at once evident, for the utilization of mature trees, or those which have ceased to grow at a satisfactory rate, tends to eliminate the ones which should be removed solely upon entomological grounds. In this way the application of methods devised with little or no reference to insects, is a procedure which the entomologist can heartily recommend.

Aside from the general preference exhibited by insects for the older trees in a forest, there are some species which select distinctly vigorous trees, saplings, or even seedlings, and these are not amenable to even partial control by the ordinary cultural methods. One of these, the white pine weevil (*Pissodes strobi*), attacks saplings or small trees, and owing to its habit of killing the leaders or terminal shoots produces a deformation of the otherwise straight trunk of the white pine. A number of the weevil eggs are placed by the parent beetle within the tender bark near the tip of the tree, and the resulting colony of larvæ work their way downwards beneath the bark. They usually pass the first lateral shoots before becoming fully grown, and destroy the part through which they have burrowed. Consequently, one of the lower side branches

must assume the place of the leader, and when it does, the axis of the tree is displaced to one side. Commonly the same tree may be attacked several times in succession, and its value to the lumberman greatly lessened.

At the present time in New England much attention is being given to the propagation of white pine, owing to the lessened supply of this valuable wood, and to the fact that it appears to be the species most suitable to replace much of the hardwood timber that is being decimated by the gipsy moth and other insects.

The white pine, both as seedlings in natural reproduction, and in areas where small nursery-grown trees have been set out for reforestation, is often severely injured and extensively killed by a small beetle, *Hylobius pales*, the adults of which eat the succulent bark from the tiny trees. The preparatory stages of the Hylobius are passed in the stumps of the cut-over areas, where their feeding causes no harm, but the voracious adults kill a large proportion of the seedling trees in the vicinity of their breeding places, and are thus a very important factor affecting the growth of the incipient white pine forest.

The saplings of certain deciduous trees also have insect pests which select them in preference to their older companions in the forests. The aspen and other poplars are frequently killed in considerable numbers by a wood-boring beetle of the genus Saperda. A single Saperda larva develops within the stem of small poplars, producing a gall-like swelling which usually spells death for the young tree.

Thus far we have considered the forest, or the individual trees, as living plants whose successful growth, or even life, may be endangered by the presence of destructive insects. From a purely economic standpoint, however, the value of a forest is measured by the quantity and quality of timber which it produces, and it is perfectly true that the lumber in mature trees killed by caterpillars or bark-beetles, is not appreciably decreased in commercial value. From an esthetic standpoint there is a vast difference between a growing or a

lifeless shade tree, but a forest tree killed by such insects as do not affect the wood, is *per se*, at the time of its death as valuable for timber as one felled for that particular purpose. There are two factors which modify such conditions. In the first place, such trees as are accessible and marketable are not necessarily those that are affected by insects, and the real loss depends upon what immediate use can be made of the timber. Following severe epidemics or invasions of insect pests, it is usually impossible to make prompt use of the killed trees and they begin rapidly to decrease in value. A case in point is the recent killing of spruce and fir by the spruce bud-worm, referred to on a previous page. The location of the areas affected is such that the utilization of the dead trees before they have become worthless is utterly impossible due to the elaborate preparations which have to be made for logging on an extensive scale. This is, unfortunately, almost always true. Secondly, the deterioration of the timber in killed trees is due in great measure to the activities of many insects which will not attack living trees, but which follow in the track of various primary destructive agencies, and reduce or utterly ruin, the value of the trees as timber. There are many species of insects of this type present in comparatively small numbers in all forests, where they find a limited food supply in the scattered trees that have recently succumbed to old age, overcrowding, lightning, windstorms, etc. As these causes of death remain tolerably constant from one year to another, there is ordinarily no great variation in the insect population, which unites with saprophytic fungi in hastening the disintegration of the dead or moribund trees.

Any sudden destruction of trees furnishes extraordinary opportunities for an increase of these insects, and they consequently appear in a secondary wave following outbreaks of insects like the Dendroctonus bark-beetles mentioned on a previous page, or in the wake of severe windstorms, brush fires and the like. For example, the pine forests of the gulf states are periodically swept by violent windstorms, embodying the unspent energy of West Indian hurricanes that have

strayed to our coast. In such an event many trees are laid flat over extensive areas. A common large longicorn beetle (*Monohammus*) which is widely distributed in this region finds these trees excellent material, and its work soon becomes apparent. The beetles deposit their eggs in little pits which they excavate in the bark, and their large succulent larvæ tunnel the wood with their food burrows until it is unfit for most purposes. Outbreaks of this kind can, of course, be foreseen much more readily than some of the other type which we have referred to previously, but the damage they cause is no less severe and the application of remedial measures is frequently very difficult.

The distinction between those insects that affect the wood or bark of living trees and those occurring in ones recently dead is not to be closely drawn, and when much dead or dying timber is present in a forest, it may furnish such favorable opportunities for the development of some species, that the whole forest becomes endangered; for when thus produced in large numbers, many wood-boring or bark-beetles that live normally in dead wood, may migrate to living trees and injure or destroy them. Such dead or decaying timber in a forest is thus a menace to the living tree population through the part which it takes in the multiplication of these forms that may on occasion affect living trees. Fire-scorched trees may in the same way be attacked by bark-beetles and succumb where uninjured trees would not have suffered, and *vice versa*, insect-killed trees, especially in the case of pure coniferous forests, may constitute a great fire menace due to the more combustible nature of the lifeless trees after the bark-beetles or other primary enemies have left them. There appears to be good evidence that some of the destructive forest fires which have occurred in the great coniferous forests of the western United States have been furthered by insects in this way.

An especially interesting example of a series of insect enemies that may follow one another in a tree as it passes from robust health into a gradual decline that ends in death,

is presented by several insects that affect the elm in New England. Since the history of the insects concerned is so well-known and the sequence of events so clearly marked, I cannot refrain from considering the matter in some detail.

In the late thirties of the last century there appeared in America near the city of Baltimore, a small European beetle known as the elm leaf-beetle (*Galerucella luteola*) which feeds

Fig. 37. The leopard moth (*Zeuzera pyrina*), an imported shade tree pest. Work of the larva in a branch from which the bark has been removed; above, the larva.

upon the foliage of various elms. The adult beetles feed on the leaves of the elm and are especially attracted to the American elm. Later they deposit their eggs upon the leaves which serve as food for the larvæ. Two or three successive broods develop in a single season and greatly weaken the elms affected. The elm leaf-beetle has gradually spread till it is now present generally throughout the more temperate sections of eastern North America.

Many years later, in 1890, there was noticed on Long Island another European insect of very different appearance and habits, the leopard moth (*Zeuzera pyrina*) (Fig. 37). This insect is a large moth which feeds in the larval stages in the

branches and trunk of a great variety of trees and shrubs. The parent moth deposits great numbers of eggs in the crevices of the bark, and the larvæ on hatching migrate to the tips of the branches where they enter small twigs. In these they construct a small circular burrow till they have increased too much in size to remain within the twig. They then leave it to enter a more commodious small branch, and may thus move into larger quarters several times before completing their growth. This requires two or three seasons and the large caterpillars often partially girdle large branches or the trunks of small trees, by tunnelling transversely through the superficial sapwood and inner living bark. The leopard moth slowly spread along the Atlantic seaboard after its establishment on Long Island, and has proved itself to be practically omnivorous, as one entomologist found it attacking over 150 different kinds of shrubs and trees. Although commonly found in many healthy and rapidly growing trees, it seems to be particularly attracted to elms that are not in prime condition. As a consequence it has found trees weakened by the elm leaf-beetle greatly to its liking and has followed the beetle very generally, reducing the vitality of the elms to a still lower ebb. At the present time the leopard moth occurs in America in only a very limited region from New Jersey to Massachusetts, but it is undoubtedly destined to cross the entire continent in the future.

Still more recently a third European insect enemy of the elm has been noticed in this country. This is a small bark-beetle (*Eccoptogaster multistriata*), which made its appearance in the vicinity of Boston about 1906. Its habits are similar to those of the Dendroctonus beetles so destructive to coniferous trees, but the elm bark-beetle attacks only sickly trees, or the dying branches of more prosperous ones. After the manner of many other bark-beetles, large numbers of individuals commonly center their activities upon selected trees which have their inner bark riddled by the burrows of the beetles. Trees weakened by the leopard moth are very susceptible to their attacks and succumb rapidly. Where the beetles are not checked by preventive measures they may

then destroy more healthy trees, especially small ones, which cannot withstand the onslaughts made by swarms of bark-beetles. The elm bark-beetle has not yet spread far beyond the point of its introduction, but like the leopard moth will unquestionably extend its range by slow steps until it occurs generally throughout the United States.

From the preceding account it can be readily seen how the elm leaf-beetle, the leopard moth and the elm bark-beetle naturally follow one another and how they affect the conditions of the elms growing where they are prevalent. At the present time the only part of the country where all three occur is included withing a few townships in eastern Massachusetts, but there the havoc they have wrought is painfully evident. In Cambridge, Boston and many surrounding towns that once boasted of many magnificent elms, only pitiful remnants remain.

A condition of this sort is of course an extraordinary instance, as all three insects are introduced species freed from many of the handicaps that hamper their multiplication in their native land, but it illustrates most beautifully in an exaggerated form what is constantly taking place in our forests. Agricultural crops do not lay themselves open to attack by insects in this way, as they are replaced by a new generation each succeeding year, and consequently their relations to insects are in this respect at least, less complex.

Lastly, there is a type of injury by forest insects which closely parallels that mentioned in connection with agricultural products in storage. Stored lumber, and even that which has been fashioned into tools or furniture is frequently damaged by insects which are capable of developing in extremely dry wood. These are, in the main, certain beetles characteristic of arid or desert regions that find a close approach to their natural environment in stored forest products. Their originally very limited distribution has been greatly extended, and they are becoming more or less cosmopolitan in range, establishing themselves as opportunity offers in places far from their native homes.

CHAPTER IV

HOUSEHOLD INSECTS

In the chapter on Insects and the Food Supply, a brief reference has already been made to certain species of plant-feeding insects that occur in stored food products. Insects of this kind form a transition between those living at the expense of growing plants and another series which may be conveniently referred to as household insects.

As a highly social animal, man has lived in communities since before the dawn of historic times. His relations with his fellows have continued to grow more complex, but the association of families into more or less permanent households is of such long and continuous standing that it has offered an opportunity for many insects to take up their abode with him. This is by no means strange, for it finds parallels among other social animals like the ants and termites. These gregarious insects almost invariably harbor in their nests, various non-social insects, known as myrmecophiles and termitophiles. These latter insects are highly modified species showing peculiar adaptations for life with their social insect hosts. The household insects associated with man are a very commonplace lot compared to the myrmecophiles and termitophiles, a condition no doubt due to the keener senses of the ants and termites in comparison with those of the human species, as well as the comparatively smaller size of all insects in relation to man. Like the less highly adapted myrmecophiles, the tiny denizens of the human household live as tolerated or persecuted guests, for hardly any would be considered as welcome additions by the ordinary person, no matter how fond he might be of dogs, cats, canaries, or other household pets.

Probably the most widespread and persistent insect visitor in houses is the housefly, named *Musca domestica* by Linnæus

in recognition of its then, well-known habits. The housefly is probably a native of India from whence it has followed man to the most remote regions of the world. It invariably occurs where human communities become established, but it is so wedded to human society that it is never to be found elsewhere. Originally a native of the tropics it can successfully

Fig. 38. A housefly killed by a parasitic fungus (*Empusa muscæ*). This fungus, which destroys countless flies, is very generally prevalent during the autumn months.

overwinter in cold regions under the conditions brought about by civilization, for it finds places of sufficient warmth to enable it to withstand the rigorous winters of very cold climates. In cool regions it is never abundant in the spring, but due to its rapid development becomes increasingly numerous as the season progresses, again to disappear rapidly in the autumn (Fig. 38). On account of its importance to public health, the habits of the housefly have already been considered elsewhere.

Many of us are familiar with the old saying that houseflies bite before a storm. Although responsible for many things, the housefly cannot bite, but the stable-fly (*Stomoxys calcitrans*), a related fly of similar size and color, with a sharp

beak, is frequently mistaken for it. The stable fly originated in Africa from whence it has spread almost as extensively as the housefly. It is a blood-sucking species, confining itself mainly to the larger domestic animals which it torments during the later months of the summer season. It does not enter houses so commonly as the housefly, nor does it very frequently bite human beings. It bites more commonly in damp sticky weather and has thus given rise to the adage of the biting housefly.

Several of the larger, noisy, metallic green or blue flies that invade houses are species which live in the larval stages upon decaying animal material. They can hardly be classed as typical household insects. Our common species occur also in Europe, but are probably native to both continents.

Another very interesting fly which almost invariably appears on windows in the early spring of our temperate regions is the cluster-fly (*Pollenia rudis*). They are somewhat larger than the housefly and of lazy, awkward flight. These flies often occur in large clusters within window casings, entering for hibernation and later seeking to escape through the glazed windows, on the approach of spring. Although a very common insect, its larval habits remain unknown as there are no authentic records of the flies having been reared.

A very abundant and annoying, tiny fly makes its appearance regularly in the latter part of the summer in most households, and frequently persists far into the winter. These little flies (Drosophila) live as larvæ in decaying fruit, with which they may easily be introduced. Our common forms appear to have been brought hither in fruits from the tropics, but their larvæ will develop readily in the decaying portions of most fruits or even the less strongly acid types of pickles. The flies are very small and appear to come from nowhere almost instantaneously when overripe fruit is exposed. From a biological standpoint they are extremely interesting as some of our most important recent discoveries concerning the inheritance of color and other characters have come from experimental studies of these tiny creatures.

Mosquitoes are very important from the standpoint of disease and have been referred to in considerable detail in a previous chapter. A few species may be regarded as truly domestic or household insects. Thus the house mosquito, *Culex pipiens*, native to Europe, but now widespread in the temperate northern regions of both hemispheres almost always breeds in close proximity to dwellings. The larvæ occur abundantly in rain barrels, cisterns and similar receptacles, and the adults enter houses with unusual persistence. In tropical countries, the same is true of the yellow-fever mosquito (*Stegomyia fasciata*) and the Filaria mosquito (*Culex quinquefasciatus*), both of which are truly domestic forms. Many other kinds of mosquitoes, especially the malarial forms readily venture indoors, but this habit is much more pronounced and constant in the case of the ones first mentioned.

Several species of cockroaches or roaches have become closely associated with man and are now widely distributed throughout the world. These insects are particularly interesting in this respect as they belong to a group of insects of very primitive character which has existed with little change over long geological periods. One would not, therefore, expect to find the numerous present-day cockroaches very adaptive or versatile in their behavior. Nevertheless, several species have cast their lot with man, since his advent, and have followed him in his wanderings. One of these, the small so-called German roach (*Blatella germanica*), is especially widespread and abundant in the cooler parts of the northern hemisphere. In spite of its name, its association with mankind probably antedates the race to which it has been referred. From its probable home in the far-east it has spread westward and reached America only at a very recent date. It was first noticed by the residents of New York City at the time the Croton aqueduct was put into operation, and was called by them the Croton bug on the belief that it had come with the water supply. This was a natural supposition as these warmth-loving insects congregate in proximity to hot-water pipes or in warm or humid kitchens. The Croton bug

is the smallest of the domestic cockroaches and is even more agile than its larger relatives. Like them it is a very general feeder, consuming all sorts of animal matter, cereal products, paste, glue, bread, etc. All of our domestic roaches show their tropical origin in their inability to withstand cold and their occurrence in cooler climates is restricted to heated dwellings.

Three of our larger roaches are *Blatta* (Fig. 39), *orientalis*, the oriental cockroach, *Periplaneta australasiæ*, the Aus-

FIG. 39. One of the larger domesticated cockroaches (*Periplaneta*). The male, shown at the left, is more slender than the female. Neither of them often remains still long enough for one to observe them closely.

tralian cockroach and *Periplaneta americana*, the American cockroach. They are thought to have originated in the orient, in Australia, and in the American tropics respectively, but have been widely distributed for so long that their provenience cannot be stated with any great assurance. All are much larger than the Croton bug, especially the Australian and American species, and they do not occur in such abundance in cooler regions. They find especially salubrious con-

ditions on shipboard where they are almost always numerous in spite of attempts to eradicate them. Such being the case, it is easy to see how they have found migration easy. Abundant in almost every shop and house in cities of the tropics, in cooler places they appear most commonly in places that are kept warm and moist. As they are especially fond of

FIG. 40. A common cricket. The male is well known on account of his chirping noise.

starchy and saccharine materials, bakeries, breweries and sugar refineries frequently harbor them in large numbers where they are a great nuisance. The repulsive cockroach odor and flavor which is often imparted to food soon becomes familiar to those who live or travel in tropical countries, and may often be recognized in sugar from northern refineries.

Not so far removed zoölogically, from the cockroaches, but of very different habits is the familiar and cheerful cricket (Fig. 40). These insects enter houses more commonly in the autumn and are far more regular visitors in the country than in cities. Their shrill chirping is an accomplishment of the male sex only. It is produced like most noises made by

insects, by rubbing together parts of the body with a rapid motion. In the case of the cricket each fore wing has a finely grained, rasping surface; when the two are opposed a succession of jerky motions made by the cricket evokes the shrill notes of far more penetrating quality than might be expected from such a small creature. Crickets remain torpid in cool weather but their activities readily respond to warmth so that the appellation of the Cricket on the Hearth is quite appropriate.

The erratic, darting flight of several tiny species of moths that periodically appear in dwellings is always a signal of alarm to the provident housekeeper, as these clothes moths are well-known to every one both as winged insects and as the cause of moth-eaten garments. Quite contrary to most moths, these forms feed in the larval state not upon foliage or vegetable material, but upon wool, fur, feathers, and material of animal origin. Their eggs are deposited very generally upon articles of clothing made from such materials and the tiny larvæ may construct cases for themselves or ill-defined burrows, lined with loose silk which they spin about them. There are several species, all rather closely similar, and probably of Eurasian origin. They are now widespread and closely associated with man. Undoubtedly under natural conditions the clothes moths were not abundant and lived a rather precarious existence, but they were well known to the ancients, whose crude garments suffered as does the highly tailored and garnished clothing of the present day.

The larvæ of several small beetles cause damage similar to that due to the clothes moths. They belong to a family of beetles known as the Dermestidæ which feed very generally upon dry animal matter of various kinds. The entomologist can speak with great feeling upon the subject of these pests, as they show a great fondness for his collections of pinned insects upon which they feed with great readiness. In households, carpets, rugs, and heavy furs frequently suffer. Two of the smaller species belong to the genus Anthrenus and are minute beetles of mottled color. The larvæ are suc-

culent, bristly grubs (Fig. 41), very resistent to extreme dryness and otherwise very tenacious of life. Their origin and habits are somewhat shrouded in mystery; at least one of our species is of European origin and the other is probably a native American insect. Their depredations have been ɪ articularly noted in households of only certain of our cities and as the adult beetles are often abundant upon flowers far from dwellings, the larvæ undoubtedly breed generally in the open.

FIG. 41. Larvæ of the carpet beetle. These bristly little insects devour furs, woolens, and all sorts of materials of animal origin, even the dried bodies of insects of other kinds. On account of this last habit, the entomologist frequently finds them feasting upon his mounted specimens.

The beetles commonly appear on window panes in the spring in company with the somewhat larger, brown *Attagenus piceus*, a related widespread insect of similar habits.

One of our most generalized and primitive wingless insects, known as Lepisma is a common household insect. It is a long tapering, scaly insect with three slender thread-like appendages at the tip of the body, rather suggestive of a fish on account of its form and glistening coat and hence commonly called the "silver-fish." The silver-fish feeds upon glue, paste or starch and will gnaw into wall-paper, starched clothing or even bookbindings to feed. It studiously avoids

the light and is rarely seen till some object is moved, when it will dart toward shelter in a most agile fashion. At the present time these insects are widespread in Europe and North America, but when or how they became companions of man remains rather doubtful.

Certain powder-post beetles referred to previously as destructive to stored wood products, occasionally make their presence in houses known in a very spectacular fashion through the collapse of a chair or other article of furniture in which they may have been present for a long time. Feeding in thoroughly dried wood, successive generations of these insects will thoroughly riddle the interior of wooden articles, avoiding the surface layer, and thus giving no evidence of their activities till the material literally crumbles into dust when it becomes too weak to support the burdens imposed upon it. The so-called "death-watch" is a related insect whose deliberate, and audible gastronomic process is responsible for the intermittent "ticks" upon which so much superstition has been based.

A few insects and spiders are attracted to houses, not by the human inhabitants, but by other domestic insects. These are much misunderstood creatures whose presence is usually incorrectly interpreted. Spiders are highly predatory, and although their webs may be unsightly, they serve greatly to reduce the numbers of flies. Other jumping-spiders, that do not spin webs, are also adept at catching flies and exhibit no habits that could render them other than pleasant companions.

Perhaps the most maligned visitors to our summer cottages, are certain large hornets which construct the intricate and wonderfully fashioned paper nests, so familiar to most of us in our early youth as objects of awe and hatred. These hornets (Fig. 42), feed their young with flies which they capture for the purpose, and their errands frequently bring them to our dwellings into which they occasionally enter. Contrary to much human tradition they do not make use of their powerful stings unless grossly annoyed and their peace-

ful mission should never be doubted. Like all social insects they defend their nests and brood with great vigor and are no respecters of persons when their home is threatened. The hornets, belonging to the genus Vespa are largely replaced in our southern states by other paper wasps known as Polistes. The larvæ of Polistes are fed by the adults upon caterpillars

FIG. 42. The White-faced Hornet (*Vespa maculata*), a frequent visitor to our porches in the summer, where she comes in search of flies.

of various kinds which are sought for and captured by the wasps, to be chewed up and distributed to their brood.

Many insects which overwinter in the adult condition find that they can avoid the rigors of the hibernating season by seeking shelter in houses. The majority of these are beetles. A variety of these creatures appear upon window panes in their search for a means of egress in the spring, and continuous observation will readily reveal the fact that some kinds are quite regular visitors.

Through his slow and tedious emergence from savagery, and undoubtedly from the much more remote stages of his evolu-

tionary development, man has retained a small number of epizoic or external body parasites, belonging to several groups of insects. The number of such insects affecting the human species appears to be generally less than that of those affecting other mammals and this may perhaps be due to the more cleanly personal habits which he has been able to acquire. If we carry the matter further back, however, to the stage of our as yet undetermined forebears, we find that the monkeys and anthropoid apes are also comparatively free from bodily insect parasites. It is possible, therefore, that we may have our much despised anthropoid ancestors to thank for this at least. It is known that monkeys actively catch and destroy fleas and other parasites, but, if the whole tale must be told — they are eaten to insure their destruction.

Several of the groups of insects which include human parasites have already been mentioned as carriers of certain diseases. From this account it will be remembered that it is rather difficult closely to draw the line between true human parasites and other blood-sucking species that only rarely attack man. There are all sorts of intergrades between species like the stable-fly or the common green-head fly of our seashore resorts, to whom human blood serves only for an occasional meal, to the body louse which passes all stages of its existence on the body upon which it is entirely dependent for food. Thus the females of certain mosquitoes suck human blood almost exclusively but are free-living creatures and during their preparatory stages are aquatic. The human flea (*Pulex irritans*) is generally restricted to man as a host during its adult life, but its preparatory stages occur in accumulations of dry organic matter of other kinds. While this is the only flea peculiar to the human species, our domesticated dog and cat have fleas peculiar to themselves, which have been widely distributed with these animals, and are common household pests in most parts of the world. Indeed, the fleas most annoying to persons are usually of the kinds regularly present on dogs, cats, or even rats, rather than the human flea.

Most closely dependent upon man are a couple of species of Cimex, known as bed-bugs. Although wingless like the flea and dependent upon human blood for food, during its preparatory stages as well as in the full-grown condition, the bed-bug is free-living. Strange to say, this insect appears not to be responsible for the transmission of any specific disease. It has been under suspicion at various times but has not so far been definitely proven to be a disease-carrier.

No reference to household insects could be complete without some mention of the numerous species that gain entrance to dwellings through the medium of food and remain there in materials kept for future use. Some of these have already been referred to in a previous chapter as enemies of stored food products. As the household pantry is only a miniature storage place for varied food products, spices, miscellaneous drugs, and sundry other materials of plant and animal origin its insect fauna is restricted only by the substances on hand and the rapidity with which those infested by insects are removed.

Certain ants are very annoying visitors to pantries into which they wander from their nearby nests to feed upon and carry home the saccharine substances of which they are very fond. These ants are usually very small species and are especially abundant in warmer countries. They are extremely persistent in their search for food and not easily discouraged.

Dry cereals of all kinds are particularly susceptible to injury by insects and it is difficult to keep even small supplies free from such pests. Several species of small moths live as caterpillars in flour, meal, rolled oats and natural breakfast foods, although they do not appear able to subsist upon the patent varieties. During the process of feeding they spin loose strands of silk which web the material together. If once admitted to receptacles containing suitable food, they pass through successive generations until the contents are completely destroyed. A great variety of beetles have similar habits, some preferring coarse materials, others the finer flours, or rice, etc.

Animal foods, such as hams, dried meats, and cheese are frequently damaged by the larvæ of certain beetles and flies which normally occur in carrion, skins, and similar substances. One of these, the cheese-skipper, is the larva of a small fly, *Piophila casei*, quite thoroughly domesticated as an inhabitant of cheese. Its name is derived from the power of the larva to skip or jump by bending and then suddenly straightening the body. If these larvæ are accidentally swallowed they are able to withstand the action of the digestive fluids and may cause very distressing symptoms. The larvæ of quite a number of other insects, mainly flies of various kinds are also capable of remaining alive in the alimentary tract, and others develop regularly beneath the skin of animals or in their alimentary tracts. Species known to affect man beneath the skin are very rare and restricted to the tropics but two common species affect cattle in this way in Europe and North America and are the cause of considerable loss. Affections of this sort are known by the general name of myiasis and human cases are fortunately of uncommon occurrence.

One of the most versatile of the pantry insects is the so-called "drug-store beetle" (*Sitodrepa panicea*), formerly of common occurrence in apothecary shops where it fed upon the stores of spices, aromatic roots, red pepper and ill-smelling or strongly flavored plant materials. The fondness shown by the grubs of this beetle for ginger and cayenne pepper is quite remarkable for such substances would seem to be rather pungent for a regular diet. Even dry tobacco forms the favorite food of the related cigarette beetle (*Lasioderma serricorne*), the larvæ of which sometimes riddle cigars with their food burrows.

This is only a very small part of the varied series of insect guests which we house and nourish, and which add to the complexity of modern life. However annoying they may be, we must admire them for the persistence with which they force themselves upon us.

CHAPTER V

THE OUTLOOK FOR THE FUTURE

From even a most cursory examination of the activities of insects as they affect directly the human species, it is very evident that insects are as a group highly injurious to man, with their influence in this direction slightly tempered by a small number of species that are directly beneficial.

This is, however, a very unfortunate way in which to regard the matter, although it is a viewpoint that has been impressed upon the minds of many of us in early childhood. Starting with the assumption that all animals were created with a view toward their usefulness to man, the old-fashioned pedagogue tried to fathom the depths of the divine mind, and to ascertain in what way many obviously noxious ones might fit into this scheme. Less orthodox, but still unfortunate from the standpoint of biological understanding, is the still too common attempt to regard all living things as either useful or injurious to man.

Nevertheless it would seem that for reasons of expediency, the economic entomologist must regard quite a considerable number of insects as falling into one or the other of these mutually exclusive categories, regardless of any consideration of the interdependence of different species, which he cannot formulate in rather exact terms. Following this a little further, it is clear that our practical dealings with insects are necessarily confined almost entirely to the eradication or reduction of numerous species which are detrimental. These include primarily the great variety that spread diseases of man or of domesticated animals, those annoying to ourselves or to domestic animals, those destructive to agricultural crops and to useful wild plants, those detrimental to forests, and those injurious to stored products.

As is also clear from the foregoing chapters, scarcely any two insects may be dealt with most satisfactorily in exactly the same way. This at once imposes upon the entomologist, the task of discovering with as great detail as possible, the exact life history and economic relations of a vast series of insects, in order that energy may not be lost in the misapplication of control measures. The last few years have seen a great improvement in our knowledge of this kind, which has already borne fruit in the rapidly increasing efficiency of practical work. We can be sure that the future will see continuous improvement along these lines.

The now widespread custom of spraying plants for the destruction of insects has been made far more efficient through careful attention to the physical and chemical properties of the materials and their physiological effects upon specific insects. In the same way fumigation with poisonous gases has been made more dependable. Various more or less fundamentally new methods of combating various insects are also continually coming into general use, usually through some ingenious application of physical or chemical knowledge to specific insects whose habits or physiological requirements at some stage of their life-cycle lay them open to attack. Thus mosquito larvæ may be eliminated by oiling the surface of the water in which they are developing, and housefly larvæ may be prevented from completing their growth in manure, by storing it in specially constructed pits. In the same way the chinch-bug, cotton-boll weevil, alfalfa weevil, certain grasshoppers, cutworms, and a great variety of other pests are commonly controlled in rather unique fashion. In fact, the most efficient means of combating many insects are not at all conventional, even to the entomologist.

The biological method of reducing the numbers of injurious insects offers at the present time, the most promising field in which to speculate concerning the future development of entomological practice. Much has already been said of the principles and details concerned in the introduction and furthering of diseases and of predatory and parasitic enemies in

the induced natural control of insect pests. This method was devised as a direct result of an understanding of the biological environment of insects, and has been applied with the greatest success to the control of imported pests. With certain modifications it has also proved of use in dealing with native insects. Its possibilities have been by no means fully explored, although it is continually receiving more attention. There is no doubt that this work will continue to increase, in our attempt to modify permanently the conditions that are otherwise met by insect species imported into new regions.

The rapid and continual influx of new insect pests into countries like our own, that enjoy extensive commercial intercourse with other parts of the globe, will undoubtedly continue in the future and the specific problems of the entomologist will become more international in their nature.

Practically all of the barriers to the dispersal of small animals like insects, that existed when living things reached their present state on the earth, have either been removed or made less certain in their action. Mountain ranges and deserts have been bridged by highways over which a continuous stream of humanity and materials is passing, bringing with it everything that can make the comfortable journey. Oceans, the most effective natural barriers, are crossed in all directions with cargoes containing many things not listed on the purser's books. In short, there is endless opportunity for small living things to migrate to all quarters of the globe. Even tropical insects find in the human communities of cooler lands, opportunity to live under climatic conditions which they could not otherwise withstand.

Such migrations of insect life have, of course, been in progress for many years, and their economic significance has long been realized. Gradually, in various parts of the world, legislative measures have been enacted, aiming at a restriction of the opportunity for noxious insects, weeds, and for animal and plant diseases to gain entrance to new regions. These are naturally modeled after the quarantine measures taken to prevent the spread of human diseases. They have

been effective in great measure in preventing the rapid spread of insects, although in the nature of the case, they could never be absolute without abolishing all commerce. In proportion to the actual efficiency of the quarantine service, and the difficulty of inspection, which naturally varies within very wide limits, the spread of insects has been impeded. In many cases the importation of certain plants and products has been prohibited. This has been done on account of the fact that the most general method of spread for agricultural, horticultural and forest insects is upon the host plant, and one of the more probable dangers is thus removed in so far as it is possible to exclude the specific materials. Whether the wholesale exclusion of food plants or their adequate inspection is to be preferred from a practical point, appears to be rather a question of opinion. So far as the ultimate result is concerned it matters little, for the immigration of undesirable insects will take place only with greater difficulty and at a slower rate, as human ingenuity is pitted against a seemingly hopeless problem.

What surprises the entomologist more than the introduction of so many insect pests into our own country, is the fact that more have not established themselves. It is evident that many insects do not become naturalized so easily as might be expected, and that when once well established, some of them spread very slowly. This is evidenced by the long time required by the gipsy moth to become abundant at the point of its introduction in New England and the subsequently deliberate extension of its range, even before adequate control measures were inaugurated. Quite probably it now occurs in many isolated places far outside its recognized range,[1] but the spread of this species and that of the browntail moth has been extremely slow in comparison with other imported species like the cabbage butterfly and the Colorado potato beetle. Such differences are partially explained by the naturally migratory habits of certain species, but not

[1] Since this was written it has been found in two other states, New Jersey and Pennsylvania.

entirely, and they may be dependent also upon the ease and rapidity with which some species become established in isolated localities.

So far as the interchange of insect pests between Europe and America is concerned, the New World has decidedly played the losing game. Whether this has a biological basis is doubtful, for undoubtedly the more thrifty and painstaking European peoples have scrutinized more carefully the things which have been received into their domain. On the other hand it is quite possible that the fauna of the palæarctic region may impose a more severe struggle for existence upon newcomers from our region than occurs in the inverse direction. At any rate America seems so far to have received more undesirable insects from abroad than has Europe.

The most promising outlook which the entomologist can enjoy is the decreasing prevalence of several of the more important insect-borne diseases. Through his efforts, coupled with those of medical investigators and sanitarians, really wonderful progress has been made in the reduction and restriction of malaria, yellow fever, plague, and typhus fever. The future will undoubtedly see a still greater activity along this line. One must not suppose, however, that the medical entomologist need not expect to receive set-backs at any time, or to have new problems thrust before him. Certain disease-bearing insects may be expected to extend their range in the same way that other insects are migrating. On account of their close association with man, many of the insect carriers of human diseases are already very widespread, but many unpleasant surprises are doubtless now hidden in little known parts of the world, from whence they may spread without warning.

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